STATE LIBRARY OF PENNSYLVANIA
docs,pa PY S9642.2A846ag
Assessment of agricultural nut
1991
0 0001 00644831 8

PA. SUSQUEHANNA RIVER BASIN COMMISSION

ASSESSMENT OF AGRICULTURAL NUTRIENT POINT SOURCE DISCHARGE FROM TILE DRAINS, SPRING AND OVERLAND RUNOFF FROM TWO FARMS, DAUPHIN COUNTY, PENNSYLVANIA

1991

★ STATE ★ LIBRARY of ★ PENNSYLVANIA
1745

STATE LIBRARY OF PENNSYLVANIA

04-37-914-5

Digitized by the Internet Archive
in 2017 with funding from
This project is made possible by a grant from the Institute of Museum and Library Services as administered by the Pennsylvania Department of Education through the Office of Commonwealth Libraries

https://archive.org/details/assessmentofagri00taki

PENNSYLVANIA STATE LIBRARY
DOCUMENTS SECTION

ASSESSMENT OF AGRICULTURAL NUTRIENT POINT SOURCE DISCHARGE FROM TILE DRAINS, SPRING AND OVERLAND RUNOFF FROM TWO FARMS, DAUPHIN COUNTY, PENNSYLVANIA

SUSQUEHANNA RIVER BASIN COMMISSION

RESOURCE QUALITY MANAGEMENT & PROTECTION DIVISION

MARCH 1991

VOID
03-55-150-4

PY S9642
.2
A846ag
c.1

The Susquehanna River Basin Commission was created as an independent agency by a Federal-Interstate Compact* among the States of Maryland, New York, Commonwealth of Pennsylvania and the Federal Government. In creating the Commission, the Congress and State Legislatures formally recognized the water resources of the Susquehanna River basin as a regional asset vested with local, State and National interests for which all the parties share responsibility. As the single Federal-Interstate water resources agency with basinwide authority, the Commission's goal is to effect coordinated planning, conservation, management, utilization, development and control of basin water resources among the government and private sectors.

SUSQUEHANNA RIVER BASIN COMMISSION

Members	Alternates
Thomas C. Jorling Commissioner, N.Y. DEC	Peter J. Bush Director, Region 8 N.Y. DEC
Arthur A. Davis Secretary, Pa. DER	James R. Grace Dep. Secretary for Resources Management Pa. DER
Torrey C. Brown Secretary, Md. DNR	Herbert M. Sachs Director, Water Resources Administration Md. DNR
Manual J. Lujan, Jr. Secretary Department of the Interior	Warner M. Depuy U.S. Commissioner Susquehanna River Basin Commission

Robert J. Bielo
Executive Director

---

* Statutory Citations: Federal - Pub. L. 91-575, 84 Stat. 1509 (December, 1970); Maryland - Natural Resources Sec. 8-301 (Michie 1974); New York - ECL Sec. 21-1301 (McKinney 1973); and Pennsylvania - 32 P.S. 820.1 (Supp. 1976).

PENNSYLVANIA STATE LIBRARY
DOCUMENTS SECTION

A new technique for nutrient management: ecosystem accounting

The best way to control nutrients in the long run may be to set up a big accounting system — a system in which balances the fertilizers and other nutrients put into an ecosystem with those taken out.

While the Nonpoint Source Evaluation Panel said its other recommendations could produce short-term results that would help the Bay, it added that the development of a "mass balance accounting system" was needed to ensure long-range success.

Simply put, a mass balance system is one in which the nutrients added to the local environment are balanced with those taken out. Either nutrient sources are removed or the uses for those nutrients must increase to keep the system in equilibrium.

That could mean reducing sources such as commercial fertilizers, animal wastes and municipal sludge while increasing activities or land uses that absorb nutrients, such as forests, wetlands and perhaps growing winter cover crops.

The panel, however, stressed that this would not be an easy job. The biggest problem is the lack of data: No one, at this point, can actually quantify the total amount of nutrient inputs — from both natural and man-made sources. Even more difficult is quantifying the amount of nutrients absorbed by crops, forests and other methods.

As a result, the panel recommended that managers commit themselves to gathering this sort of data so a future change could be made to a sustainable, mass-balance accounting system.

"Although it may take several years to establish a high level of confidence in the mass balance approach, this procedure, in conjunction with existing techniques, is certain to prove more determinate than the current approach alone," the panel said.

Alliance for the Chesapeake Bay
BAY JOURNAL
Vol. 1, No. 1, March 1991

ASSESSMENT OF AGRICULTURAL NUTRIENT POINT SOURCE DISCHARGE FROM TILE DRAINS, SPRING AND OVERLAND RUNOFF FROM TWO FARMS

DAUPHIN COUNTY, PENNSYLVANIA

Prepared By:

Charles S. Takita
Arthur N. Ott
John D. Graham
John J. Hauenstein

The work upon which this report is based was supported by federal funds provided by the United States Environmental Protection Agency under a Water Pollution Control-Statewide Interstate Program Grant Number I-003992-90-0

Printed on recycled paper

SUSQUEHANNA RIVER BASIN COMMISSION
1721 N. Front Street
Harrisburg, PA 17102-2391

March 1991

Publication No. 135

PY S9642.2
Takita, Charles S.
Assessment of agricultural
nutrient point source

ACKNOWLEDGMENTS

Paul Clugston, farmer at Halifax, and Ann and Colonel Tom Darlington, owners of the land farmed by Bill Harmon, have been extremely cooperative and supportive throughout the project. The Pennsylvania Department of Environmental Resources, Bureau of Laboratories, performed all of the water and part of the soil chemical analysis. Dr. Les Lanyon, Pennsylvania State University Agronomy Department, provided valuable assistance in soil sampling and analysis. Information on crop yields and crop and manure analyses was provided by reports of a special project entitled "Developing and Implementing Nutrient Management Systems for Pennsylvania Farms", conducted under Dr. Lanyon for the Chesapeake Bay Program.

TABLE OF CONTENTS

Page

ABSTRACT 1

INTRODUCTION 2

  Background 2
  Purpose and Scope 3
  Description of the Study Area 4
  Sample Collection and Analysis 7

HYDROLOGY 12

  Precipitation 12
  Tile Drain/Spring/Surface Water 15

    Ground water 17
    Relationship of ground water to the tile drains 17

AGRONOMIC PRACTICES 18

  Halifax Farm 18

    1987 18
    1988 19
    1989 20

  Enterline Farm 21

    1987 22
    1988 22
    1989 22

NUTRIENT CONCENTRATIONS AND LOADS 23

  Halifax Farm 23

    1987 23
    1988 26
    1989 29

  Enterline Farm 39

    1987 39
    1988 41
    1989 41

Page

NUTRIENT ACCOUNTABILITY 50

Halifax Farm 50

1987 50
1988 52
1989 54

Enterline Farm 56

1987 56
1988 56
1989 59

SOIL NITROGEN STATUS - HALIFAX FARM 59

SUMMARY AND CONCLUSIONS 62

Halifax Farm 63
Enterline Farm 65

REFERENCES 69

APPENDIX

A Nutrient Summary Statistics

Halifax tile drain - 1987 .... A-1
Halifax tile drain - 1988 .... A-3
Halifax tile drain - 1989 .... A-6

Halifax spring - 1987 .... A-9
Halifax spring - 1988 .... A-11
Halifax spring - 1989 .... A-14

Halifax surface - 1989 .... A-17

Enterline tile drain - 1987 .... A-19
Enterline tile drain - 1988 .... A-21
Enterline tile drain - 1989 .... A-23

Enterline surface - 1989 .... A-26

LIST OF TABLES

Page

1. Trade name and common name of pesticides 13

2. Monthly and total precipitation at the Halifax and Enterline farms, July 1987 through December 1989 14

3. Seasonal and total water discharge from the Halifax and Enterline farms, July 1987 through December 1989 16

4. Water-weighted average concentrations of nutrients from the Halifax farm tile drain, spring and surface runoff, September 1987 through December 1989 33

5. Monthly water-weighted average concentrations of nitrite plus nitrate from Halifax farm tile drain, spring and surface runoff, September 1987 through December 1989 36

6. Annual nutrient load discharged from the Halifax farm tile drain, spring, and surface flow, and its total point source discharge, September 1987 through December 1989 37

7. Annual water discharge, yields, and mean concentrations of nutrients in combined runoff from the Halifax farm 38

8. Summary of pesticide application and detection in water samples at the Halifax farm 39

9. Water-weighted average concentrations of nutrients from the Enterline farm tile drain and surface runoff, July 1987 through December 1989 45

10. Monthly water-weighted average concentrations of nitrite plus nitrate from the Enterline farm tile drain and surface runoff, July 1987 through December 1989 46

11. Annual nutrient load discharged from the Enterline farm tile drain and surface flow, and its total point source discharge, July 1987 through December 1989 48

12. Comparison of annual water discharge, yields, and mean nutrient concentrations between the total drainage area (24.63 acres) and the corn area (12.57 aces) at the Enterline farm 49

13. Summary of pesticide application and detection in water samples at the Enterline farm 50

14. Halifax farm, 1987 51

15. Halifax farm, 1988 53

16. Halifax farm, 1989 55

Page

17. Enterline farm, 1987 ... 57

18. Enterline farm, 1988 ... 58

19. Enterline farm, 1989 ... 60

20. Soil nitrogen status, Halifax farm ... 61

LIST OF FIGURES

1. Location of the farms selected for study ... 5

2. Location of monitoring facilities on the Halifax farm ... 8

3. Location of monitoring facilities on the Enterline farm ... 8

4A. Tile drain monitoring site at Halifax farm ... 9

4B. Surface runoff monitoring site at Halifax farm ... 9

5A. Spring monitoring site at Halifax farm ... 10

5B. Automatic sampler at Halifax and Enterline farms ... 10

6A. Surface runoff and tile drain monitoring site at the Enterline farm ... 11

6B. Tile drain monitoring site at the Enterline farm ... 11

7. 1987 Nitrite plus nitrate concentration and average daily water discharge, Halifax tile drain ... 24

8. 1987 Nitrate plus nitrate concentration and instantaneous water discharge, Halifax spring ... 25

9. 1988 Nitrite plus nitrate concentration and average daily water discharge, Halifax tile drain ... 27

10. 1988 Nitrite plus nitrate concentration and instantaneous water discharge, Halifax spring ... 28

11. 1989 Nitrite plus nitrate concentration and average daily water discharge, Halifax tile drain ... 30

12. 1989 Nitrite plus nitrate concentration and instantaneous water discharge, Halifax spring ... 31

Page

13. Relationship of average concentration of nitrate to depth of water-bearing zone below water table 36

14. 1987 Nitrite plus nitrate concentration and average daily water discharge, Enterline tile drain 40

15. 1988 Nitrite plus nitrate concentration and average daily water discharge, Enterline tile drain 42

16. 1989 Nitrite plus nitrate concentration and average daily water discharge, Enterline tile drain 43

ABSTRACT

The Halifax farm field drain and spring are located below the water table for most of the year and are, therefore, believed to be collection points for the very shallow ground water. This situation thus provides a relatively enclosed shallow flow system which allows the calculation of a reasonable nutrient budget. The measured runoff ranged from 16 percent to 51 percent of the annual precipitation.

The annual N and P loss to the combined water outflow of a tile drain, spring, and overland runoff from the 10.19 acre Halifax farmed drainage area ranged from 23 to 119 lbs/ac of N and 0.21 to 0.56 lb/ac P.

The Enterline farm field drain is located at a depth which is above the water table most of the time and, therefore, only flows during and immediately following precipitation events. Unlike the Halifax flow system, this flow system ranged only from 5 percent to 11 percent of the annual precipitation and, therefore, does not warrant a nutrient budget.

The nutrient loss to the water outflow of the measured Enterline flow system ranged from 4 to 10 lbs/ac N and 0.06 to 0.11 lbs/ac P. Since slightly more than half of the drainage area is farmed and most of the remainder wooded, the yield per acre farmed area is 8 to 20 lbs/ac N and 0.11 to 0.22 lbs/ac P.

The 4 to 10 lbs/ac N loss at Enterline is similar to the average annual N losses estimated for farmed Susquehanna River subbasins that are at least 50 percent forested. The intensely farmed Conestoga River basin averages 33 lbs/ac N loss and a 2.44 lbs/ac P loss. The Halifax farm, which does not have non-farm dilution runoff, appears in the high N range, but neither farm remotely approaches the P loss found in the Conestoga or other highly farmed basins.

The application rate of animal manure at the Halifax farm is primarily for its N content. There appears to be little soil build up of available residual N but does result in a substantial build up of total P.

INTRODUCTION

Background

An agricultural practice which has received little attention as a major conveyance for the removal of agricultural chemicals from farmland is the artificial subsurface drainage system (tile drain). A possible reason for this lack of attention is that the utilization of tile drains is considered an important conservation practice. Among specific benefits often cited, the most important are that the drains: a) provide aeration for maximum plant growth; b) increase the length of growing season and c) remove toxic substances which might retard plant growth by removing the leachate through the tile drain; and d) provide greater storage capacity for water following precipitation events.

When farm management principles such as contouring, strip cropping, and terracing, are practiced along with subsurface drainage, much of the precipitation not subjected to evapotranspiration should move through the soil and away from the cultivated fields. The drainage system collects water from the fields and usually discharges it through a single outlet directly into ditches and feeder streams. Unlike surface runoff, which normally stops flowing shortly after a precipitation event ends, subsurface discharge in the tile drain systems may continue to flow long after a precipitation event, depending on the level of the water table and the amount of water retained by the soil.

There are numerous tile drains installed on farms in the Susquehanna River basin with little known about the quality and quantity of their discharges. It is important that these discharges be characterized so that the combined effects of these point sources can be evaluated.

Purpose and Scope

This study provides an indication of the quality and quantity of the nutrient discharge from agricultural tile drainage systems which drain two dissimilar farming operations. One is an upland 150 head dairy farm (Clugston/Halifax farm) which grows its own grain, hay, and silage and is fertilized primarily with dairy and chicken manure and is supplemented with commercial fertilizer. The second farm (Darlington/Enterline farm) is primarily a lowland corn producing site that has only commercial fertilizer applied. The quantity of discharge from the two tile drain systems was monitored continuously while the nutrient chemistry was monitored periodically during both non-storm and storm periods.

The study attempts to calculate a partial cropland nutrient budget, primarily for the dairy farm by determining the nutrient input, output and storage. Nutrient input was to be determined by the quality and quantity of manure and commercial fertilizers applied to the fields. The output was to be determined by the: a) crop yield and its nutrient content; b) quantity of tile drain discharge and its nutrient content; and c) quantity of surface runoff and its nutrient content. Storage was determined from soil nutrient data.

Description of the Study Area

The project area is located in a major valley within the Appalachian Mountain section of the Valley and Ridge Physiographic Province. Drainage is to the Susquehanna River via Armstrong Creek (Halifax farm) and Powell Creek (Enterline farm) (Figure 1).

The Halifax farm is located about one and a half miles east of Halifax, Pa. The farming operation supports a 150 head dairy farm. The monitoring facilities are located in 10.19 acres of cropped fields characterized by gentle to moderate slopes with drainage toward several swales. The farmer (Clugston) uses a no-till planter for corn and adds a chemical starter fertilizer with the seed. The fields are primarily fertilized with dairy and chicken manure.

The soil on this farm is the Calvin-Leck Kill soil complex which is formed from material weathered from acid red shale and sandstone. The soil has moderate permeability and moderate to low available moisture capacity. The percolation rate meets the minimum State requirement for septic tank disposal fields, but the soil has severe limitations for this use because bedrock is near the surface (two feet - four feet) and there is danger of contaminating the ground water. The soil has a low to moderate "native" fertility rating. The soil is considered marginal for farming because it is a shallow soil that contains a high proportion of coarse rock fragments, has a moderately low CEC (cation exchange capacity) and is inherently high in acidity because of its acid parent material. The estimated average productivity for this soil (U.S. Department of Agriculture, 1972) is:

Corn	- grain	70	bushels/acre
	silage	14	tons/acre
Hay	- alfalfa	2	tons/acre
	grass/legume mix	1.5	tons/acre

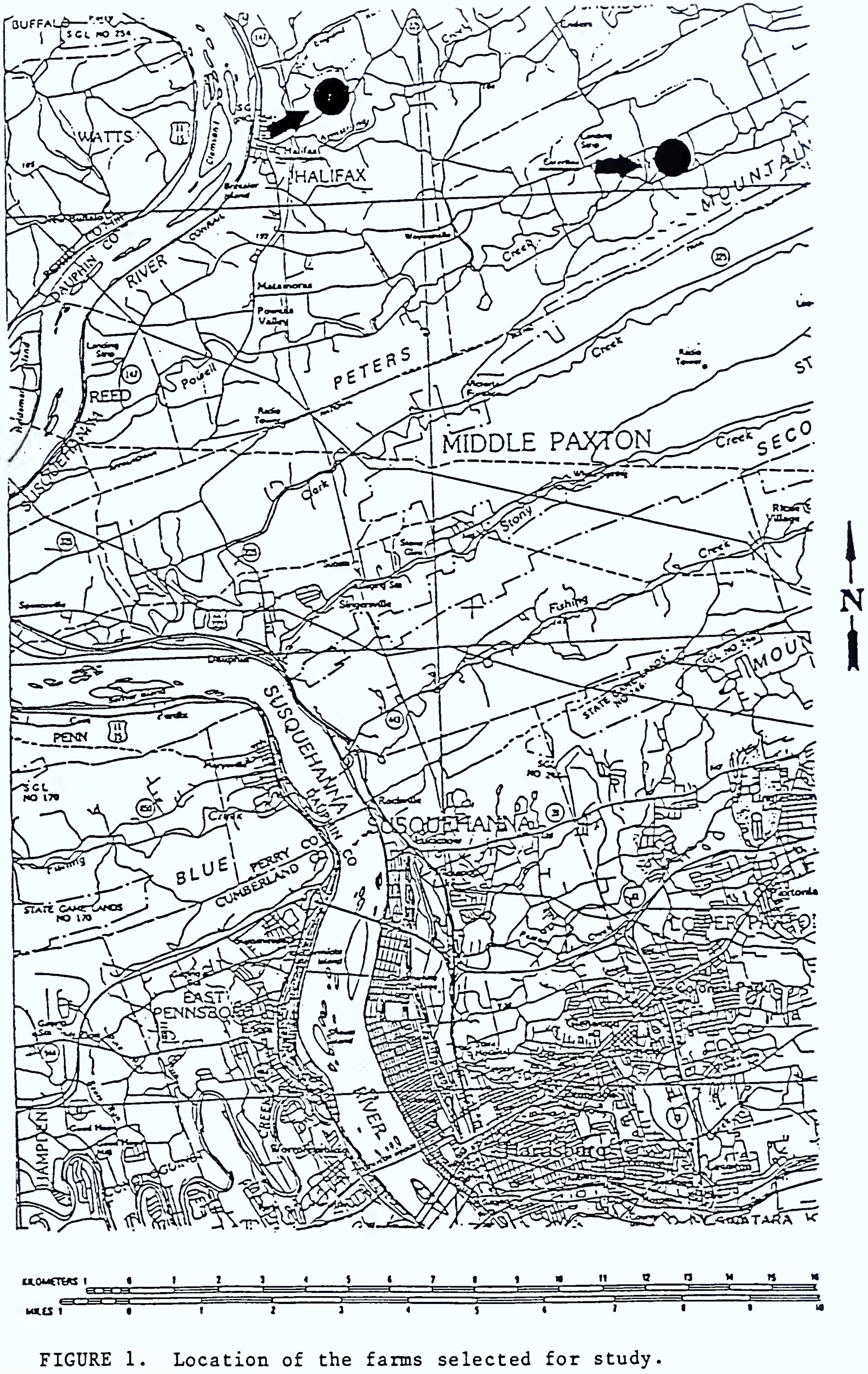

FIGURE 1. Location of the farms selected for study.

The Enterline farm is located near Enterline, Pa. The operator (Harmon) applies chemical fertilizer and utilizes minimum tillage to grow corn. The study area consists of three corn fields (upper, middle, and lower) totaling 12.57 acres separated by wooded strips. Slopes range from relatively steep in the upper field to nearly flat in the lower field, which is in the flood plain of Powell Creek. The Dekalb channery sandy loam supports two corn fields above the tile drain, while the Calvin-Klinesville shaly silt supports the wooded buffer strips between the corn fields. The third corn field, the field supporting the tile drain, is in the flood plain and is located on a Barbour silt loam.

The Dekalb soil is formed in material weathered from gray sandstone. The soil has a moderately rapid permeability and low available moisture capacity. Because the available moisture capacity is low, this soil is only fairly well suited to most farm crops. It is strongly acid and low in clay content. The estimated average productivity for this soil is:

Corn - grain	48	bushels/acre
silage	9.6	tons/acre
Hay - alfalfa	1.6	tons/acre
grass/legume mix	1.5	tons/acre

The Barbour silt loam is a deep, well drained flood plain soil and is formed by sediments washed mainly from red noncalcareous shale and sandstone. Permeability and available moisture is moderate. This soil is strongly acid to neutral and is estimated to have the highest average productivity for the soils of the two farms:

Corn - grain	102	bushels/acre
silage	20.4	tons/acre
Hay - alfalfa	3.75	tons/acre
grass/legume mix	3	tons/acre

Sample Collection and Analysis

Figures 2 and 3 show the locations of the data collection sites. Figures 4A, 4B, 5A, 5B, 6A, and 6B are photos of the installed monitoring equipment. Samples from the Halifax farm were collected from the tile drain, a spring, and surface runoff channeled through a flume. Samples from the Enterline farm were collected from the tile drain and surface runoff channeled through a weir.

Monitoring systems were constructed during the spring of 1987 on each of the farms to measure the quantity and quality of the water discharged from the respective farms. The subsurface monitoring systems consisted of pits which bisected the tile drains. These pits contained v-notch weirs and continuous water level recorders. Each site was equipped with an automatic water sampler which collected water samples at predetermined time intervals during storms.

Surface runoff monitoring systems were installed at the Halifax farm during the spring of 1988 and at the Enterline farm in the fall of 1988. The monitoring system on the Halifax farm consisted of flume installed on the grassed waterway with wing-walls to direct all surface flows through the flume. A continuous stage recorder was installed to automatically record any flow through the flume during storm events. Water samples were collected automatically at prescribed time intervals. The monitoring system at the Enterline farm consisted of a weir and a continuous stage recorder installed in a drainage ditch at the edge of the field.

Initially, water discharge was sampled weekly and storm flows sampled hourly to determine changes in constituent concentrations over the course of storm events. The variations were found to be gradual so the sampling frequency was retained at weekly for non-storm samples and daily for storm samples. Surface runoff samples were collected automatically every hour since the runoff events were infrequent and of short duration.

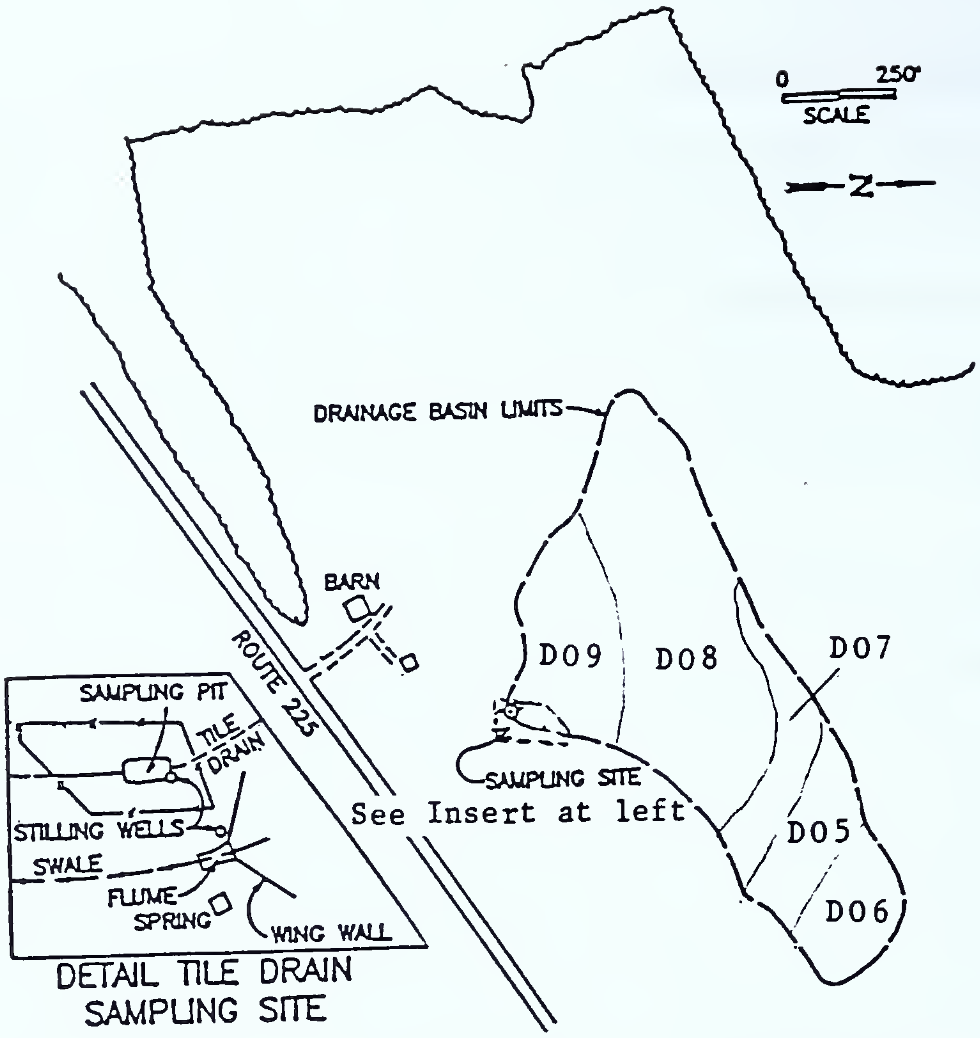

FIGURE 2. Location of monitoring facilities on the Halifax farm.

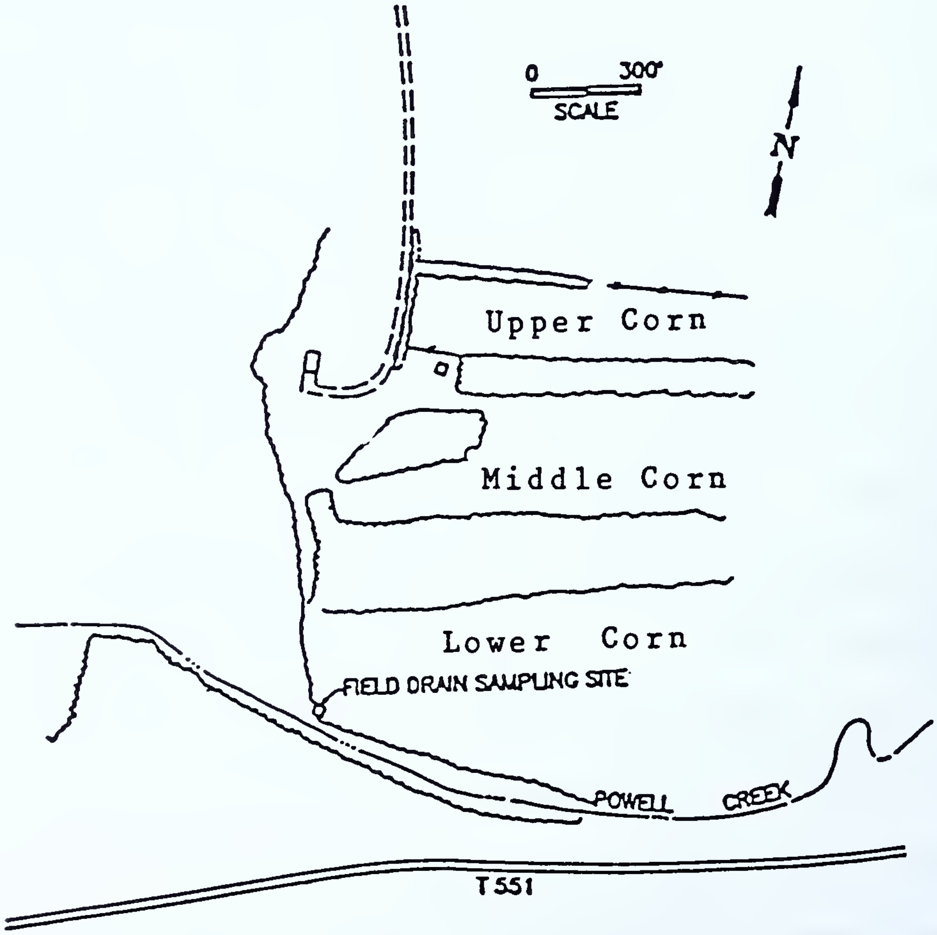

FIGURE 3. Location of monitoring facilities on the Enterline farm.

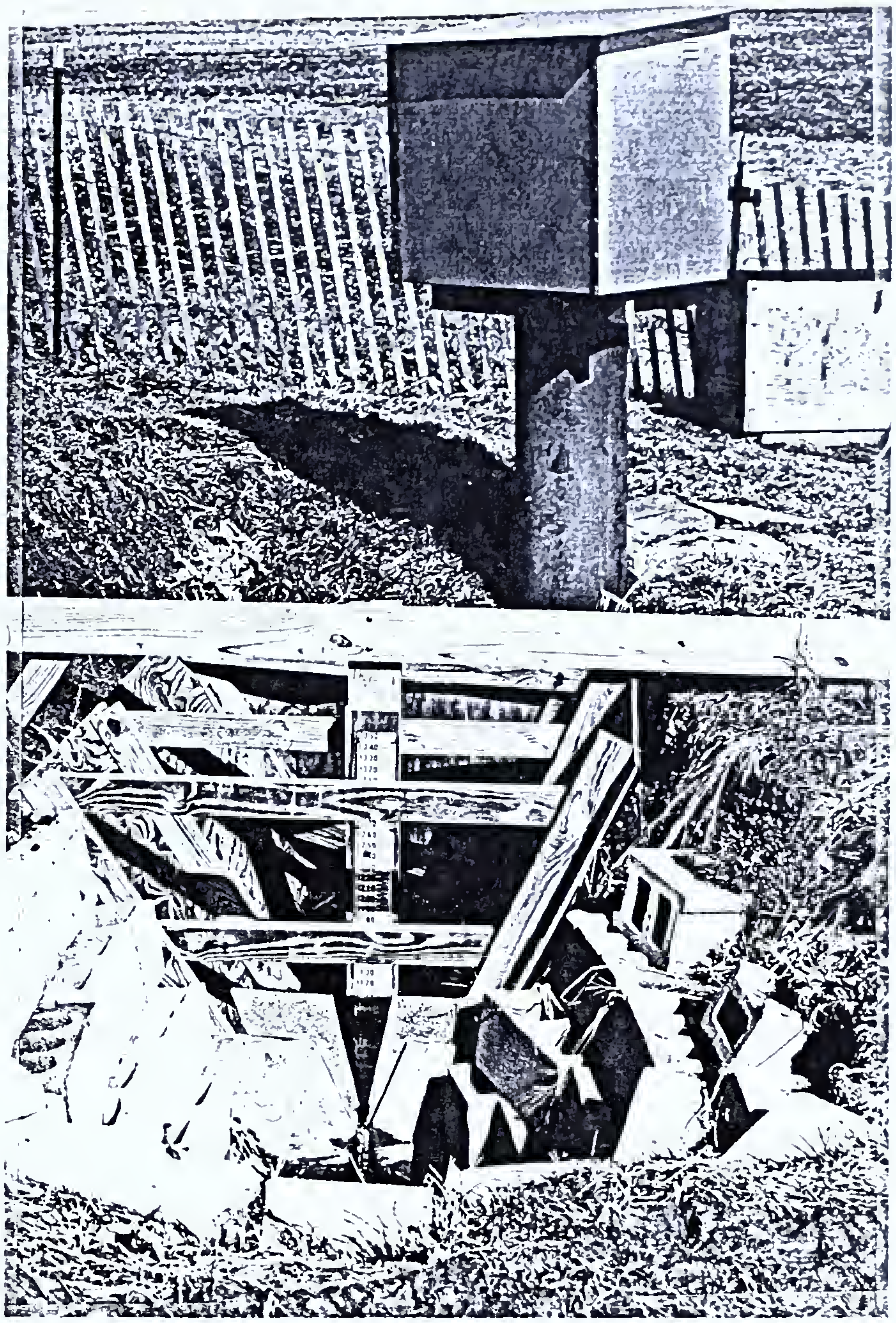

FIGURE 4B. Tile drain monitoring site at Halifax farm.

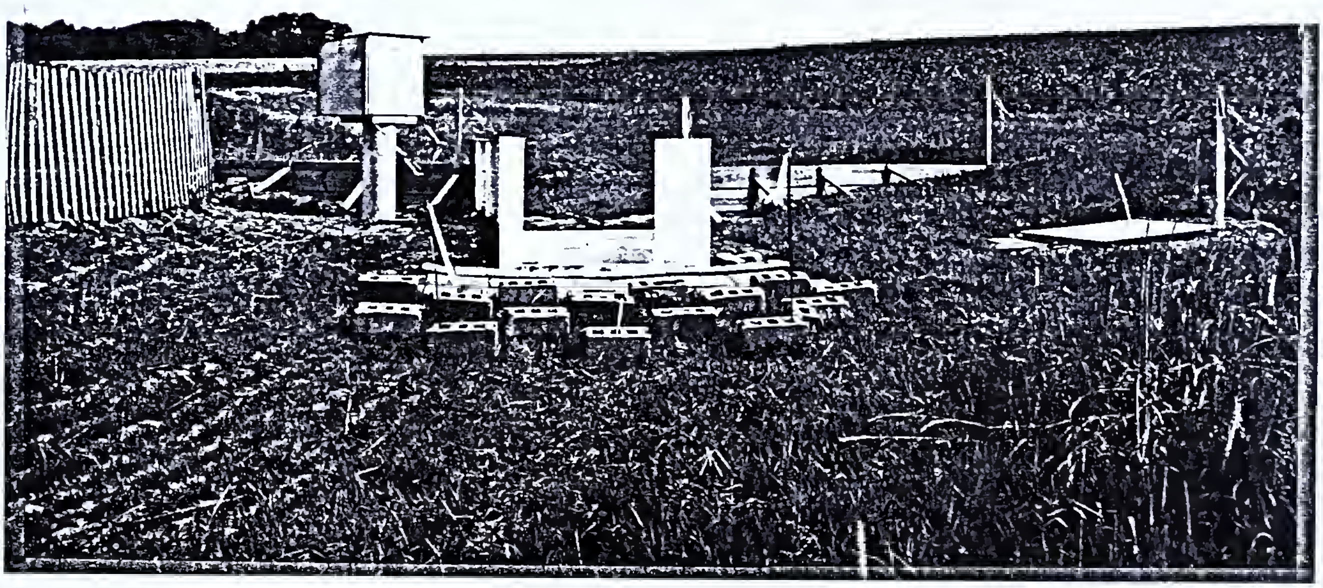

FIGURE 4B. Surface runoff monitoring site at Halifax farm.

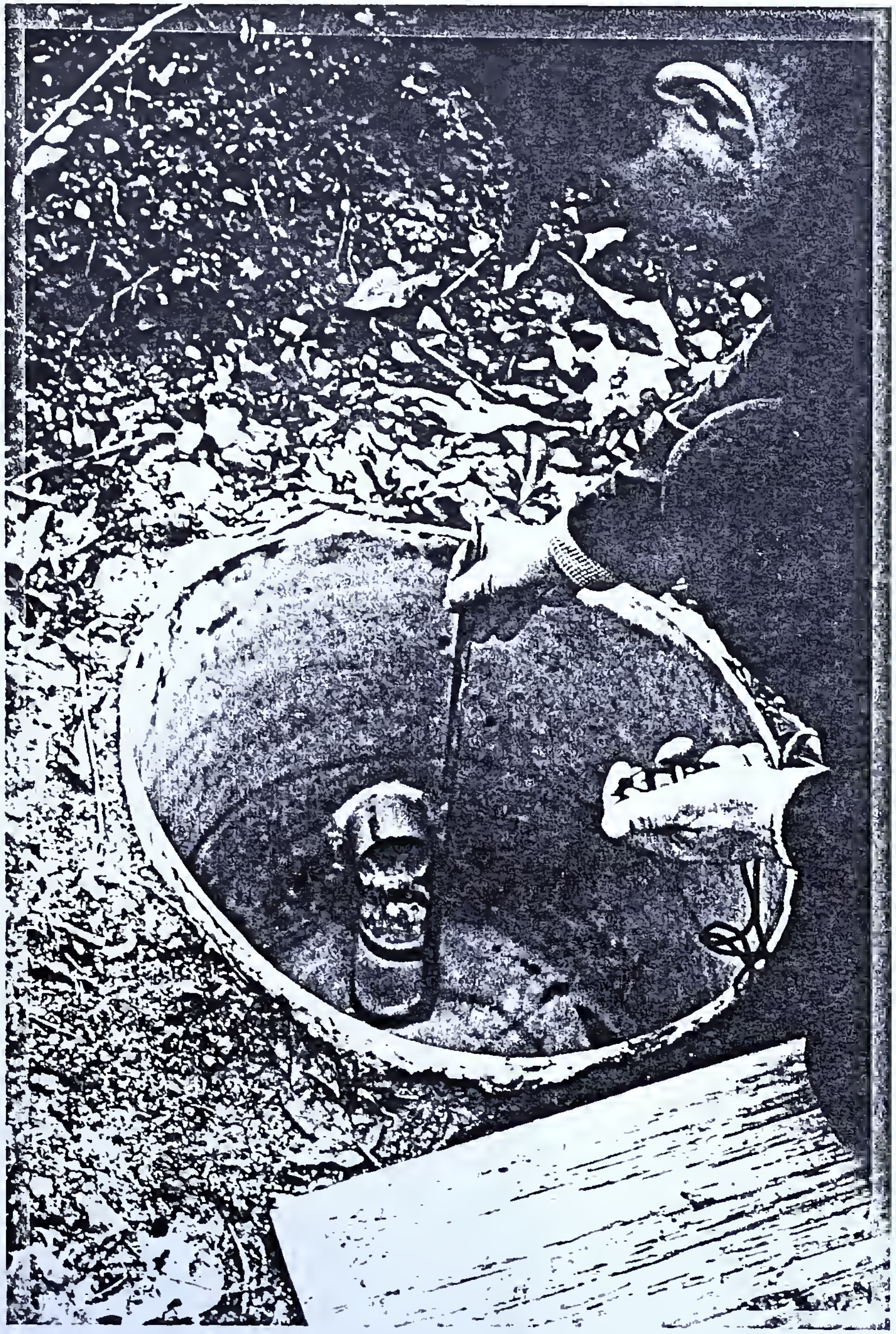

FIGURE 5A. Spring monitoring site at Halifax farm.

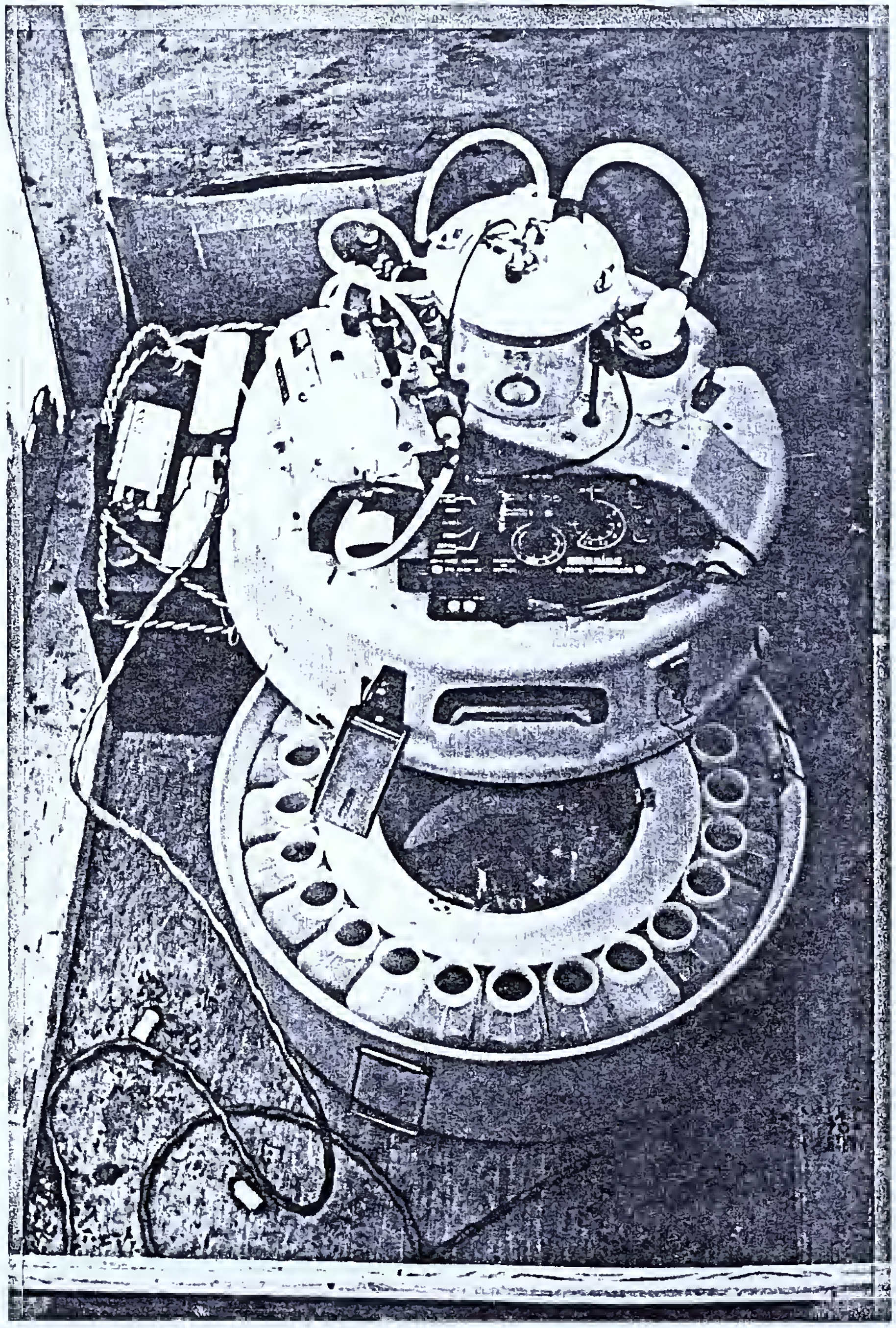

FIGURE 5B. Automatic sampler at Halifax and Enterline farms.

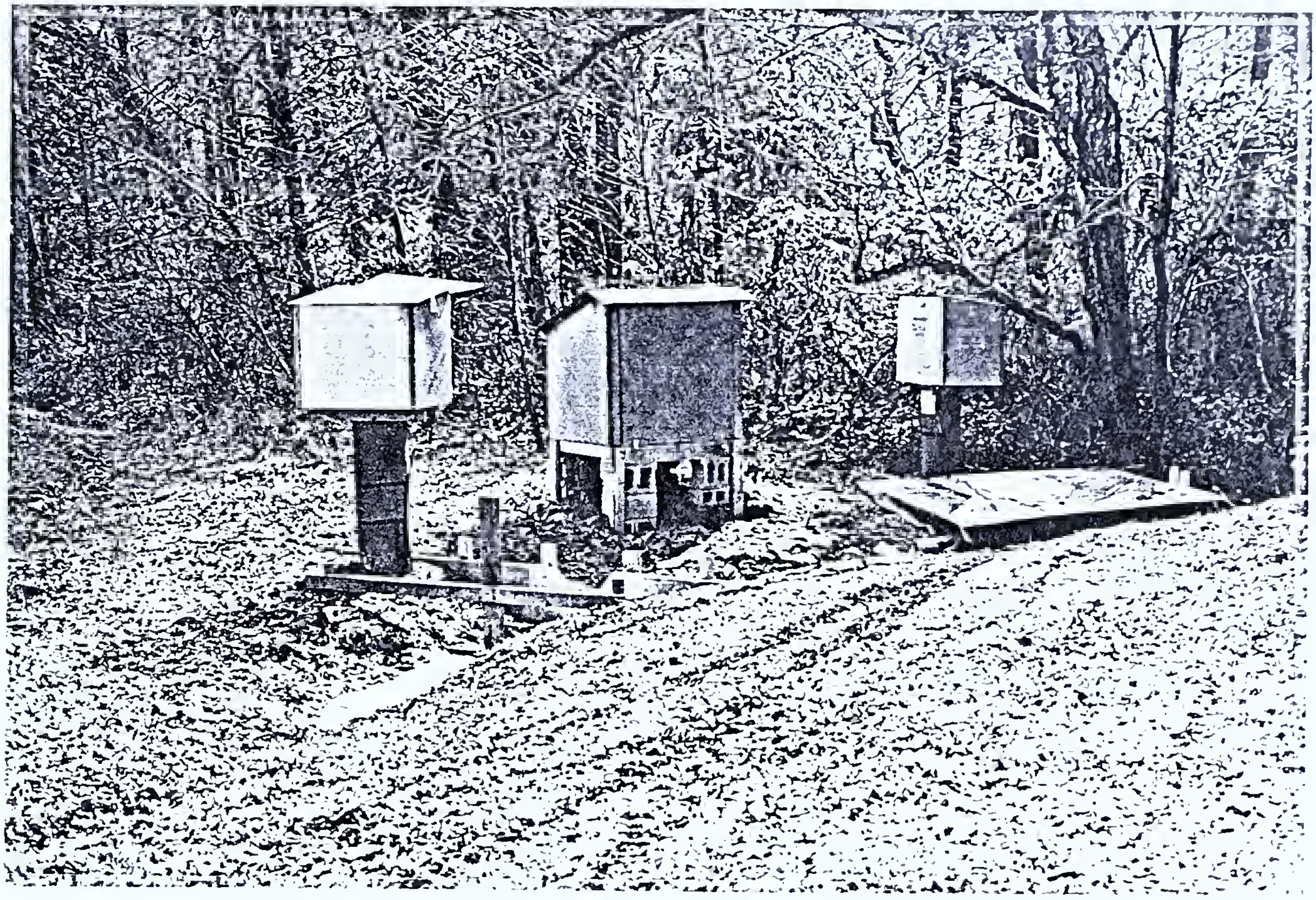

FIGURE 6A. Surface runoff and tile drain monitoring site at the Enterline farm.

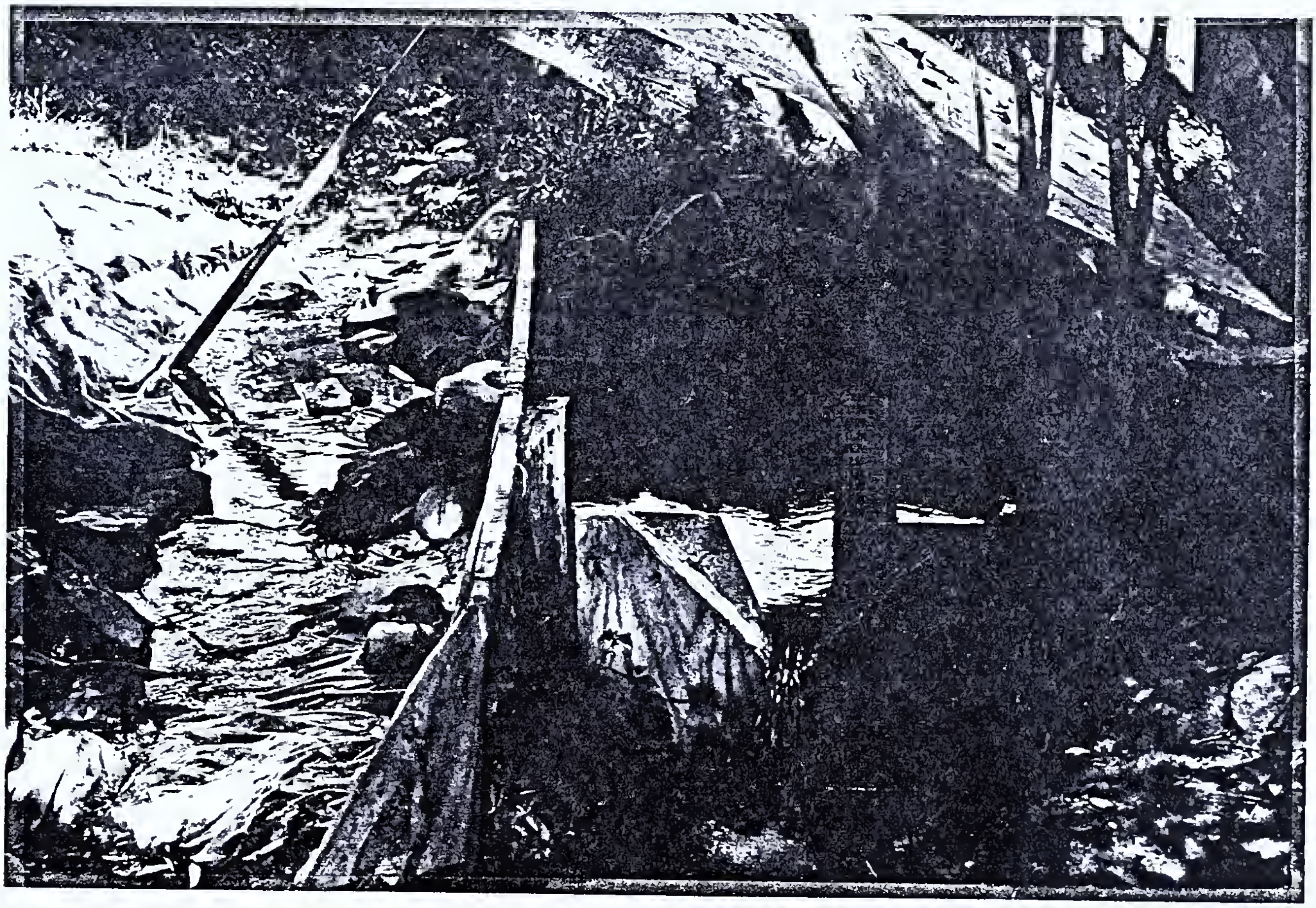

FIGURE 6B. Tile drain monitoring site at the Enterline farm.

The water samples were analyzed for the following constituents:

- pH - Field
- Specific Conductance - Field
- Nitrite plus Nitrate - N, Total
- Ammonia - N, Total
- Kjeldahl-N, Total
- Phosphorus - P, Total
- Organic Carbon, Total

Water samples were collected for pesticides analysis. These analyses were specific for the pesticides applied by the farmers. Table 1 provides the trade names and the common names of the pesticides used by the farmers.

Soil samples were also collected twice a year and analyzed for nitrates, kjeldahl nitrogen, and orthophosphate content.

HYDROLOGY

Precipitation

Precipitation averages 41.4 inches annually at the Department of Commerce long-term station at Newport, Pa. Precipitation data recorded by observers at each farm are shown in Table 2. Precipitation was 20.3 inches at the Halifax farm for the last four months of 1987 and 26.7 inches at the Enterline farm for the last six months of 1987. Precipitation in 1988 was 31.4 inches and 33.5 inches at Halifax and Enterline, respectively, well below the normal of 41.4 inches. Calendar year 1989 was the wettest year with above normal precipitation at both sites.

TABLE 1. Trade name and common name of pesticides

Trade Name[1]	Common Name
Banvel - Herbicide	Dicamba
Bicep - Herbicide	Atrazine and Metolachlor
Bladex - Herbicide	Cyanazine
Dual - Herbicide	Metolachlor
Extrazine - Herbicide	Atrazine and Cyanazine
Furadan - Insecticide	Carbamate
Gramoxone - Herbicide	Paraquat
Lorox - Herbicide	Linuron
Pounce - Insecticide	Permethrin
2-4D - Herbicide	2-4D

---

[1] Use of trade names in this report is for identification purposes only and does not imply endorsement by the Susquehanna River Basin Commission.

TABLE 2. Monthly and total precipitation at the Halifax and Enterline farms, July 1987 through December 1989.

	1987		1988		1989	
	Halifax	Enterline	Halifax	Enterline	Halifax	Enterline
Month	inches					
January			1.81	1.35	1.57	1.64
February			2.54	2.73	1.60	2.17
March			1.86	2.12	2.63	3.78
April			1.75	2.18	1.10	1.07
May			4.92	6.27	8.33	9.97
June			1.73	1.52	7.09	8.06
July		2.95	3.45	3.79	9.47	6.99
August		3.92	3.14	2.50	3.95	3.11
September	13.09	10.48	3.40	2.99	3.32	3.39
October	2.54	3.04	1.83	2.64	4.93	5.43
November	3.29	4.55	3.99	4.24	1.92	3.04
December	1.33	1.80	1.01	1.12	1.0*	1.03
TOTAL	20.3	26.7	31.4	33.5	46.9	49.7
	10^3 gallons					
TOTAL	5,600	17,900	8,700	22,100	13,000	33,200

* Estimated

Tile Drain/Spring/Surface Water

Point source water discharge during the period of data collection are listed in Table 3. Water discharge measured for only part of 1987 was greater than that for all of 1988 at both the Halifax and Enterline farms. The greatest water discharge was measured in 1989 which was also the wettest year.

The point source water discharge measured at the Halifax farm for the last four months of 1987 was 28.0 percent of the precipitation for the same period. The tile drain discharged 21.0 percent of the precipitation, while the spring discharged only 7.0 percent. There was a significant surface runoff event in September and several smaller ones after September which were not measured.

The water discharge at Halifax in 1988 was 16.2 percent of precipitation. There were no surface runoff events recorded in 1988; the first year that the surface runoff monitoring flume had been in place, and precipitation in 1988 was 10.0 inches below the normal of 41.4 inches. Taylor and Edwards (1989) reported that a five-month long ground water recession occurred during the late spring and summer of 1988, as a result of the below normal precipitation. This would indicate that the ground-water recharge probably was minimal and water loss in 1988 was primarily due to evapotranspiration. The spring accounted for the higher percentage of discharge with 9.3 percent of precipitation compared to 6.9 percent of precipitation for the tile drain.

Total water discharge measured in 1989 from the Halifax farm was 49.5 percent of precipitation. The tile drain accounted for 30.9 percent of precipitation, while the spring accounted for 13.8 percent for a total of 44.7 percent of precipitation being discharged from a point source. The surface runoff accounted for 4.8 percent of precipitation.

TABLE 3. Seasonal and total water discharge from the Halifax and Enterline farms, July 1987 through December 1989.

	Halifax Farm			Enterline Farm	
	Tile Drain	Spring	Surface	Tile Drain	Surface
Season	10^3 gallons				
1987					
Jul - Sep	693	8.00		697	
Oct - Dec	467	388		1,350	
Annual Total	1,160	396		2,050	
Total Discharge	1,560			2,050	
1988					
Jan - Mar	245	396		967	
Apr - Jun	229	205		462	
Jul - Sep	13.0	59.0			
Oct - Dec	115	146		2.00	
Annual Total	602	806		1,430	
Total Discharge	1,410			1,430	
1989					
Jan - Mar	431	378		413	
Apr - Jun	1,470	573	49.0	1,610	171
Jul - Sep	1,500	567	307	426	141
Oct - Dec	616	275	276	402	271
Annual Total	4,020	1,790	632	2,850	583
Total Discharge	6,440			3,430	

Water discharge measured at the Enterline farm was 11.4 percent of precipitation in 1987, 6.5 percent in 1988, and 10.3 percent in 1989. Surface water accounted for 1.8 percent of precipitation in 1989. Water loss on this farm is believed to be by evapotranspiration and underflow directly into the adjacent stream.

Ground water

The aquifer at both farms consists of interbedded sandstone and shale. Most ground water in these rocks occurs in secondary openings, fractures and bedding plane partings. The water table is approximately parallel to the land surface, with the surface- and ground-water divides occurring in generally the same areas.

The ground water is in continuous motion from the highest elevations near the divides to the swales or stream valleys where it discharges via springs or seeps. In this geologic setting, active ground-water flow may occur to depths of several hundred feet below land surface, however, the zone of most active ground water flow is within a few tens of feet below the water table.

The water table is shallowest in the swales and valleys and deepest at the divides, or hilltops. Measured water levels at the Halifax farm range from about 25 feet at the divide to three feet near the swale containing the field drain (Taylor and Edwards, 1989). Water levels are significantly deeper at the Enterline farm, ranging from nearly 65 feet to about 7 feet.

Relationship of ground water to the tile drains

Evidence indicates that the field drain, which had nearly continuous flows, on the Halifax farm is located, at least for most of the year, below the water table and is, thus, a collection point for the shallow ground water.

It was noted (Taylor and Edwards, 1989) that ground water levels associated with a well drilled next to the tile drain could be used to predict when the tile drain would be discharging water. The spring, located adjacent to the field drain, is also a collection point. Combined, they accounted for about 16.2 percent of the precipitation on the monitored basin in 1988. This is probably equivalent to about half of the total ground-water recharge that occurred during this period.

In contrast, the drain at the Enterline farm, is located at a depth which is above the water table most of the time; the drain only flows during and following precipitation events. During 1988, the drain accounted for only 6.5 percent of the precipitation falling on the monitored basin. Because this drain has several gravel inlets, a part of this was probably direct surface water infiltration. Thus, most of the ground-water flow at this site bypasses the drain and is discharged to Powell Creek.

AGRONOMIC PRACTICES

Halifax Farm

The Halifax farm study area is 10.19 acres which include parts of five contoured fields designated D05 (1.34 acres), D06 (1.78 acres), D07 (1.24 acres), D08 (3.1 acres), and D09 (2.73 acres).

1987

Corn silage was harvested from the five fields in September 1986. Pit manure was applied, but not incorporated, in October 1986 to fields D07, D08, and D09. Field D07 received 47,000 pounds of manure, D08 received 124,000 pounds manure, and D09 received 109,200 pounds of manure. Rye was then planted in all fields. Commercial starter fertilizer was not applied.

Liquid N was broadcast over all five fields in March 1987 at the rate of 40 lbs/ac. The rye was cut for use as haylage in early May. Corn was planted a week later in all fields along with 100 lbs/ac of 7-21-7 corn starter fertilizer. Herbicides were sprayed on all fields at the end of May 1987 at a rate of 3.0 qts/ac Bicep; 0.5 pts/ac Dual; 1.5 pts/ac Gramoxone; 4.0 ozs/ac Pounce. All fields were sidedressed with liquid N at the end of June at the rate of 120 lbs N/ac. Corn was cut during the first week of September for use as silage.

Pit manure was applied at the rate of 46,700 lbs/ac during the third week of October to field D05, the only field to receive manure. Manure was not incorporated.

Rye was planted during the first week in November in D05 and D07. Fertilizer was not applied. Fields D06, D08, and D09 were left fallow.

1988

A frozen field, D06, received 21,900 lbs/ac of heifer feedlot manure on February 1.

The rye fields, D05 and D07, received broadcasted liquid N during the latter part of March at the rate of 50 lbs/ac. The two fields were also sprayed with 0.3 pts/ac of Banvel and 0.5 pts/ac of 2-4D. Low magnesium lime was applied April 18, to fields D05 and D06 at the rate of 2 tons/ac.

Corn was planted in fields D08 and D09 on May 12. Starter fertilizer 7-21-7 was drilled at the rate of 115 lbs/ac. The herbicides Extrazine, Dual, and Gromoxone were applied at the rate of 3.0 lbs/ac, 1.5 pts/ac and 1.5 pts/ac, respectively, on May 14.

Rye haylage was cut May 26-27, on D05 and D07.

Corn was planted on D05 on June 4, and on D06 and D07 on June 6. Starter fertilizer 7-21-7 was drilled at a rate of 115 lbs/ac and the herbicides Extrazine, Dual and Gramoxone were sprayed at the rate of 3.0 lbs/ac, 1.5 pts/ac and 1.5 pts/ac, respectively.

All fields were sidedressed with liquid N at the rate of 50 lbs/ac on July 20.

Corn was cut for silage from all fields during the period from September 29 through October 27.

Field D05 had 7,750 lbs/ac chicken manure broadcast on October 24, and an additional 21,100 lbs/ac dairy pit manure on November 17-18. The field was tilled with a disk harrow November 19.

Field D08 had 11,800 lbs/ac chicken manure broadcast October 24, 7,350 lbs/ac heifer feedlot manure October 28, and 25,350 lbs/ac dairy pit manure on October 31. Field was tilled with a disk harrow November 3. An additional 24,036 lbs/ac dairy pit manure was broadcast November 9.

Field D09 had 7,870 lbs/ac chicken manure broadcast November 13, and tilled with a disk harrow the following day. Heifer feedlot manure (4,900 lbs/ac) and 62,000 lbs/ac of dairy pit manure was applied from October 28-November 3. Manure was incorporated with a disk harrow on November 3, 1988.

Rye was planted in all fields on November 23.

1989

All fields had rye topdressed with 40 pounds liquid N per acre on April 5.

Rye was harvested as haylage in all fields May 23-25.

Field D05 was tilled with a disk harrow June 23. Sudex (sorghum/sudan grass) was planted the same day. Sudex was harvested August 3 and September 29. The field was tilled with a disk harrow October 5, and rye planted (drill) October 6.

D06 had diary pit manure broadcast at the rate of 61,680 lbs/ac on June 5 and 27. The field was tilled with a disk harrow on June 27. Corn was planted July 3. On July 8, the herbicide Extrazine was sprayed at the rate of 3 pts/ac and 3.0 lbs/ac, respectively. The insecticide Pounce was sprayed at rate of 4.0 ozs/ac on the same day. Corn silage was cut October 24.

Field D07 had dairy pit manure applied at the rate of 60,600 lbs/ac on July 13-15. The field was tilled with a disk harrow and sudex planted on July 15. Sudex was harvested September 27-28. The field was tilled with a disk harrow October 5.

Corn was planted in fields D08 and D09 on June 12. The herbicides Lorox and Bladex were sprayed June 17, at the rate of 1.0 lbs/ac and 2.0 qts/ac, respectively. The insecticide Pounce was sprayed on the same time at the rate of 4.0 ozs/ac. Corn was cut for silage October 12-13.

Rye was planted in fields D05 and D07 on October 6.

Enterline Farm

The study area consists of three corn fields designated upper (3.85 acres), middle (4.59 acres), and lower (4.13 acres), with the upper field bordered by a hedge row and 2.06 acres of soybeans belonging to an adjacent farm. The three corn fields are separated by 8.85 acres of wooded strips and 1.15 acres of lawn. Thus, the total drainage area is 24.63 acres, of which 12.57 acres are planted to corn. The fertility status and contribution to the drainage of the upper 2.06 aces of soybeans is unknown and has been discounted because the soybean yields have been visually poor. Therefore, the measured water discharge represents runoff from 24.63 acres, while the nutrient discharge is assumed to be contributed solely by the 12.57 acres in corn.

1987

The application of 1.6 tons of urea (46 percent N) was tilled with a disk harrow in April, followed by the planting of corn in May. Starter fertilizer 7-21-7 was drilled at the rate of 250 lbs/ac. Herbicides (Bicep, Bladex, and Lorox) were applied at the rate of 2.5 pts/ac, 1.5 pts/ac, and 1 lb/ac, respectively. The insecticide Furadan was applied at the rate of 10 lbs/ac. The corn was harvested in October and yielded an average of 75 bushels per acre. The corn fields were left fallow over winter.

1988

Calcitic limestone was applied at the rate of 0.4 T/ac and tilled with a disk harrow in April.

The application of 1.57 tons of urea was tilled with a disk harrow in May, followed by the planting of corn, along with 150 lbs/ac of 10-20-10 corn starter. The corn was harvested in October and yielded an average of 15 bushels per acre. Rye was seeded in the fall as a cover crop.

1989

Fertilizer was not applied during this year. The rye was mowed and left in the field.

NUTRIENT CONCENTRATIONS AND LOADS

Nutrient summary statistics showing the maximum, minimum, average and median values of measured instantaneous water discharge and nutrient concentrations by year and seasons are provided in Appendix A. Only nitrite plus nitrate and total phosphorus are discussed here because nitrogen and phosphorus are the primary nutrients of concern. Nitrite plus nitrate constitutes the major portion of total nitrogen and is the nitrogen species most responsive to changes in water discharge.

Halifax Farm

1987

Measured nitrite plus nitrate concentrations (Appendix A) from the tile drain ranged from 16.1 mg/l to 33.2 mg/l in 1987, with an average concentration of 26.2 mg/l. The median value was 26.5 mg/l. Nitrite plus nitrate concentrations from the spring ranged from 18.0 mg/l to 29.8 mg/l with an average and median of 22.43 and 21.84 mg/l, respectively. Figures 7 and 8 show the nitrite plus nitrate concentration and the corresponding water discharge values from the tile drain and spring, respectively, plotted against time. The heavy rains in September appear to have caused leaching of nitrite plus nitrate from the soil, as evidenced by the high concentrations and then a gradual decrease towards the end of the year in the tile drain (Figure 13). The seasonal average and median also indicate this decrease. Concentrations in the spring were similar to those in the tile drain, although slightly lower, but did not appear to show the same trend. Both the tile drain and the spring show a marked increase in concentration on or about November 19, when the water discharge showed a significant increase. Manure was applied on Field D05 in late October and this may indicate a delayed response.

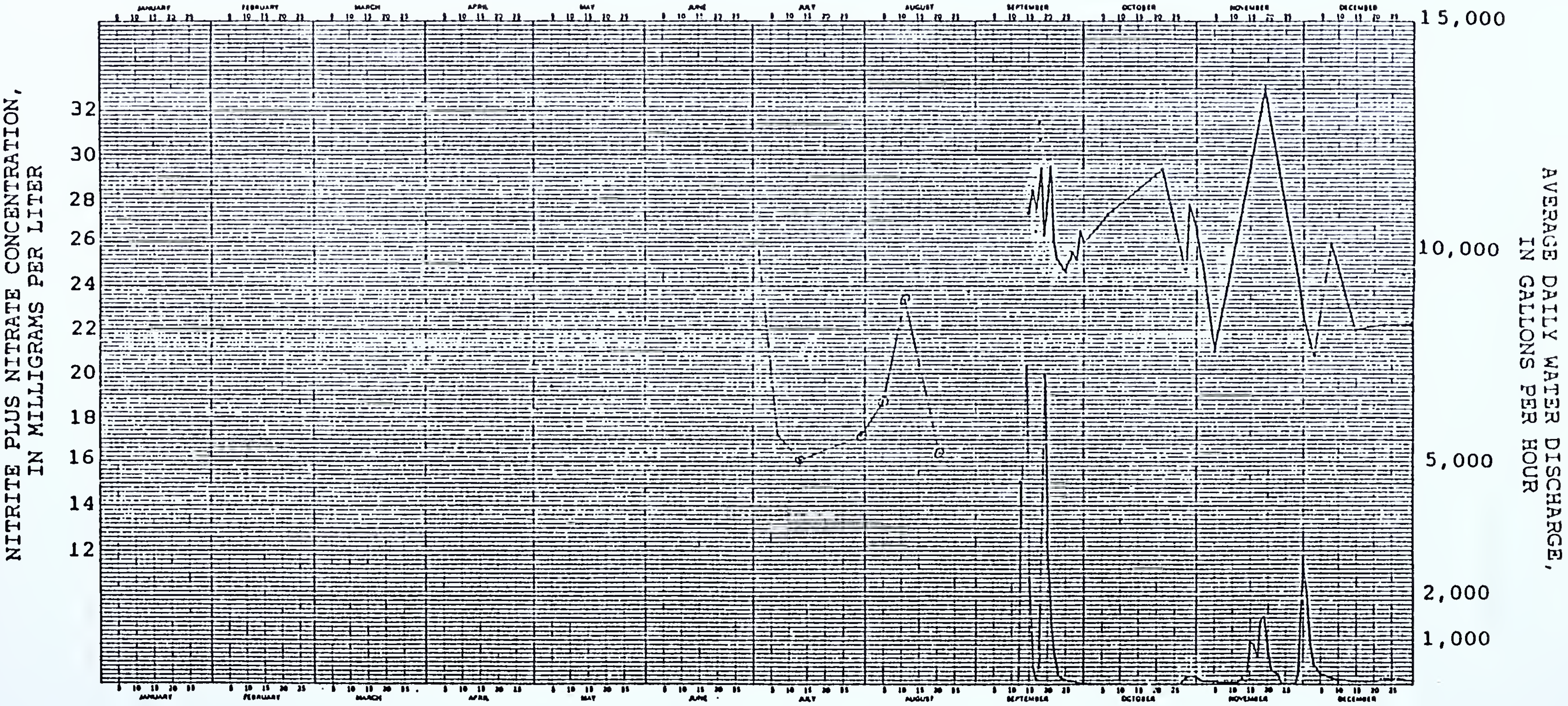

FIGURE 7. 1987 Nitrite plus nitrate concentration and average daily water discharge, Halifax tile drain

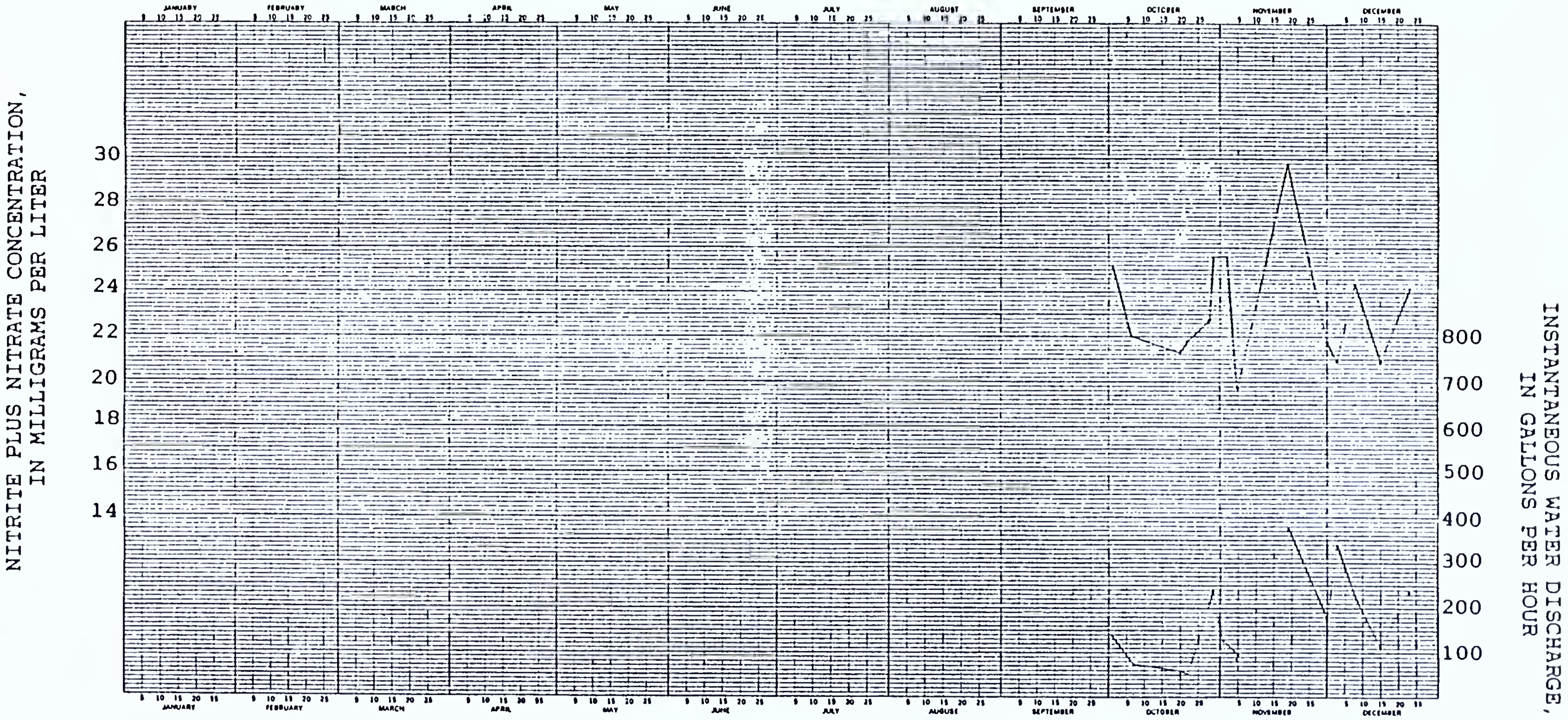

FIGURE 8. 1987 Nitrite plus nitrate concentration and instantaneous water discharge, Halifax spring

Total phosphorus concentrations ranged from 0.01 mg/l to 4.9 mg/l with an average of 0.16 mg/l in the tile drain. The median value was 0.08 mg/l. Total phosphorus concentrations in the spring ranged from 0.02 mg/l to 0.09 mg/l with the average and median values of 0.03 mg/l and 0.02 mg/l, respectively.

1988

Measured nitrite plus nitrate concentrations (Appendix A) in the tile drain ranged from 13.4 mg/l to 22.8 mg/l with an average and median value of 19.21 mg/l and 19.4 mg/l, respectively. Nitrite plus nitrate concentrations in the spring ranged from 7.1 mg/l to 22.3 mg/l with an average of 19.0 mg/l and a median of 19.4 mg/l. Nitrite plus nitrate concentrations and the corresponding water discharges plotted in Figure 9 indicate that the concentrations from the tile drain show a gradual decreasing trend and then a slight increase during the latter part of the year. Although a trend is not very evident in Figure 10 for the spring, the seasonal statistics show the same trend. These trends do not reflect any response to the agronomic practices. Precipitation in 1988 was 10 inches below normal. Since only 16.2 percent of the precipitation was accounted for by the tile drain and spring, the greatest part of the precipitation was probably lost through plant uptake and evapotranspiration. The implication would be that most of the water and associated nutrients from fertilizer applications were taken up by the plants and did not reach the tile drain and spring. The nitrite plus nitrate concentrations were very similar in the tile drain and spring throughout the year.

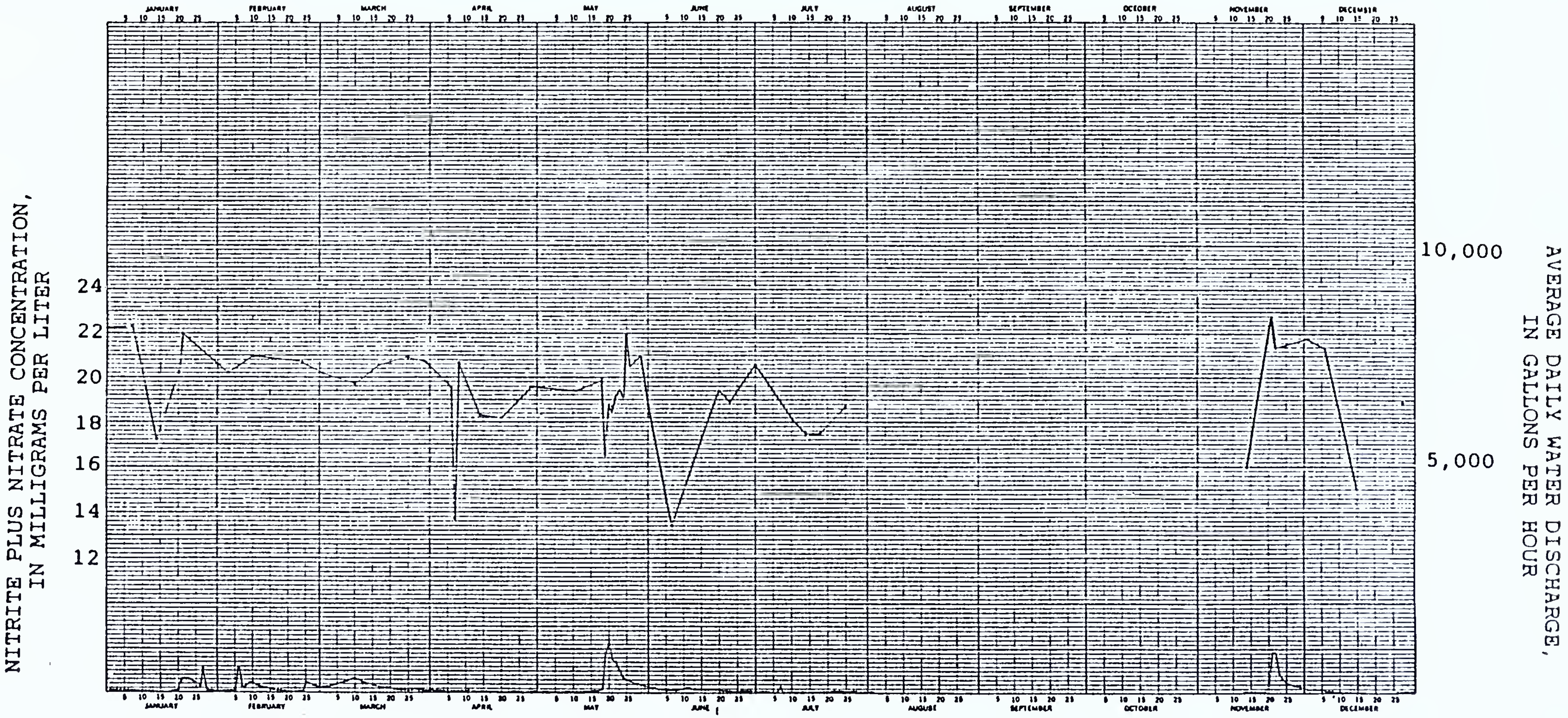

FIGURE 9. 1988 Nitrite plus nitrate concentration and average daily water discharge, Halifax tile drain

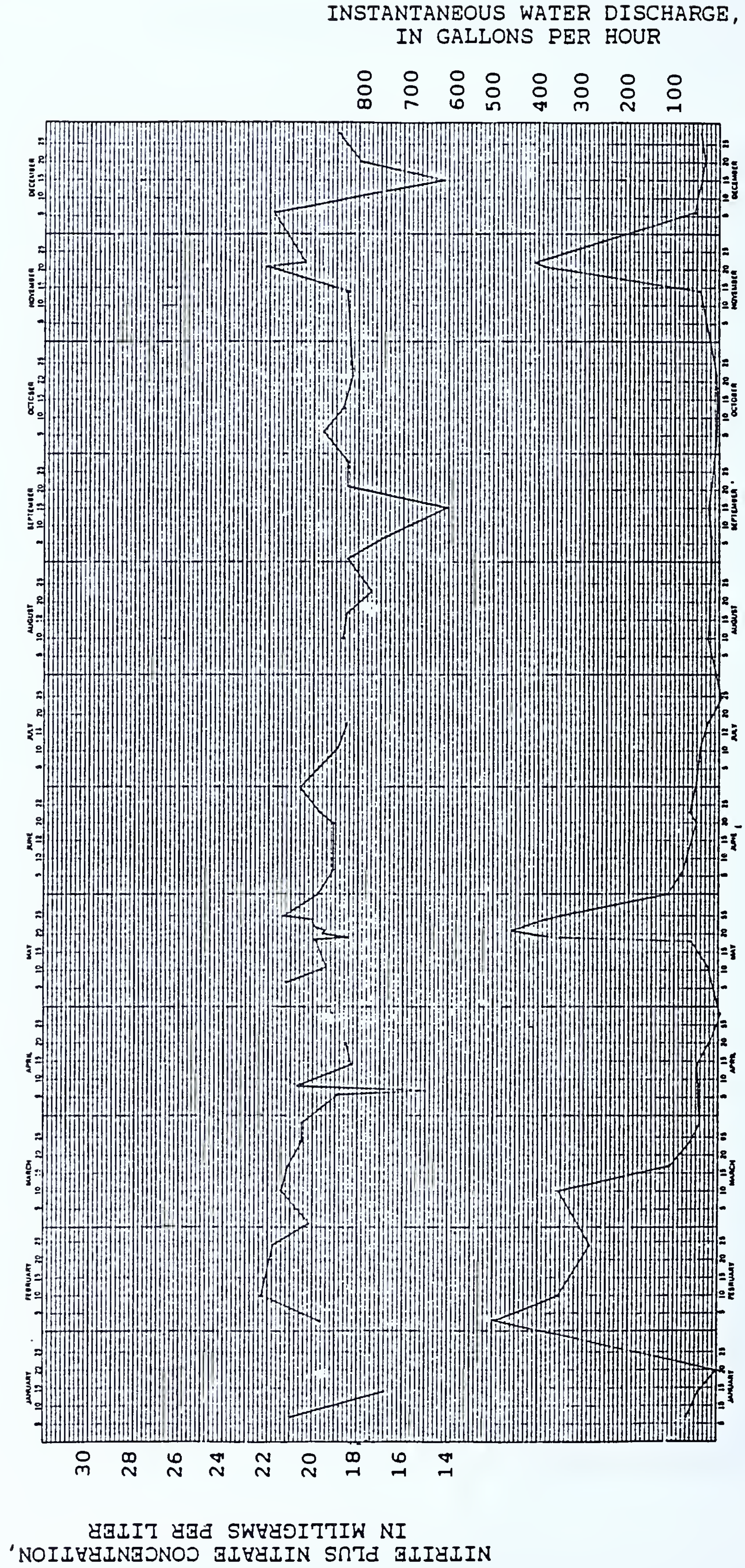

FIGURE 10. 1988 Nitrite plus nitrate concentration and instantaneous water discharge, Halifax spring

Total phosphorus concentrations in the tile drain range from 0.02 mg/l to 4.1 mg/l with an average and median value of 0.20 mg/l and 0.03 mg/l, respectively. Total phosphorus concentrations in the spring range from 0.02 mg/l to 0.51 mg/l with an average 0.04 mg/l and a median of 0.03 mg/l.

1989

Measured nitrite plus nitrate concentrations plotted in Figure 11 do not show any obvious seasonal trends in concentrations from the tile drain. Seasonal summary statistics (Appendix A) show a slight increase in the spring season and then a slight decrease. The tile drain concentrations, which were higher than in 1988, ranged from 16 mg/l to 26.3 mg/l with an average of 21.6 mg/l and a median of 26.5 mg/l. Nitrite plus nitrate concentration from the spring plotted in Figure 12 show a slight increase during the spring season and the summer. The concentrations in the spring, which were also higher than in 1988, ranged from 10.6 mg/l to 29.1 mg/l with an average and median concentration of 22.1 mg/l and 22.3 mg/l, respectively. Heavy rains occurred during the same period that the increases in concentrations were observed. Manure and fertilizer were applied during this same period.

Surface runoff was measured for the first time in 1989 and the nitrite plus nitrate concentrations ranged from 0.15 mg/l to 23.7 mg/l with an average of 5.84 mg/l and a median of 3.96 mg/l.

Total phosphorus concentrations ranged from 0.02 mg/l to 0.19 mg/l and averaged 0.04 mg/l with an median of 0.03 mg/l in the tile drain. The spring concentrations ranged from 0.02 mg/l to 0.36 mg/l and averaged 0.04 mg/l with a median of 0.03 mg/l. Total phosphorus in surface runoff ranged from 0.1 mg/l to 2.0 mg/l with an average of 0.88 mg/l and a median of 0.76 mg/l.

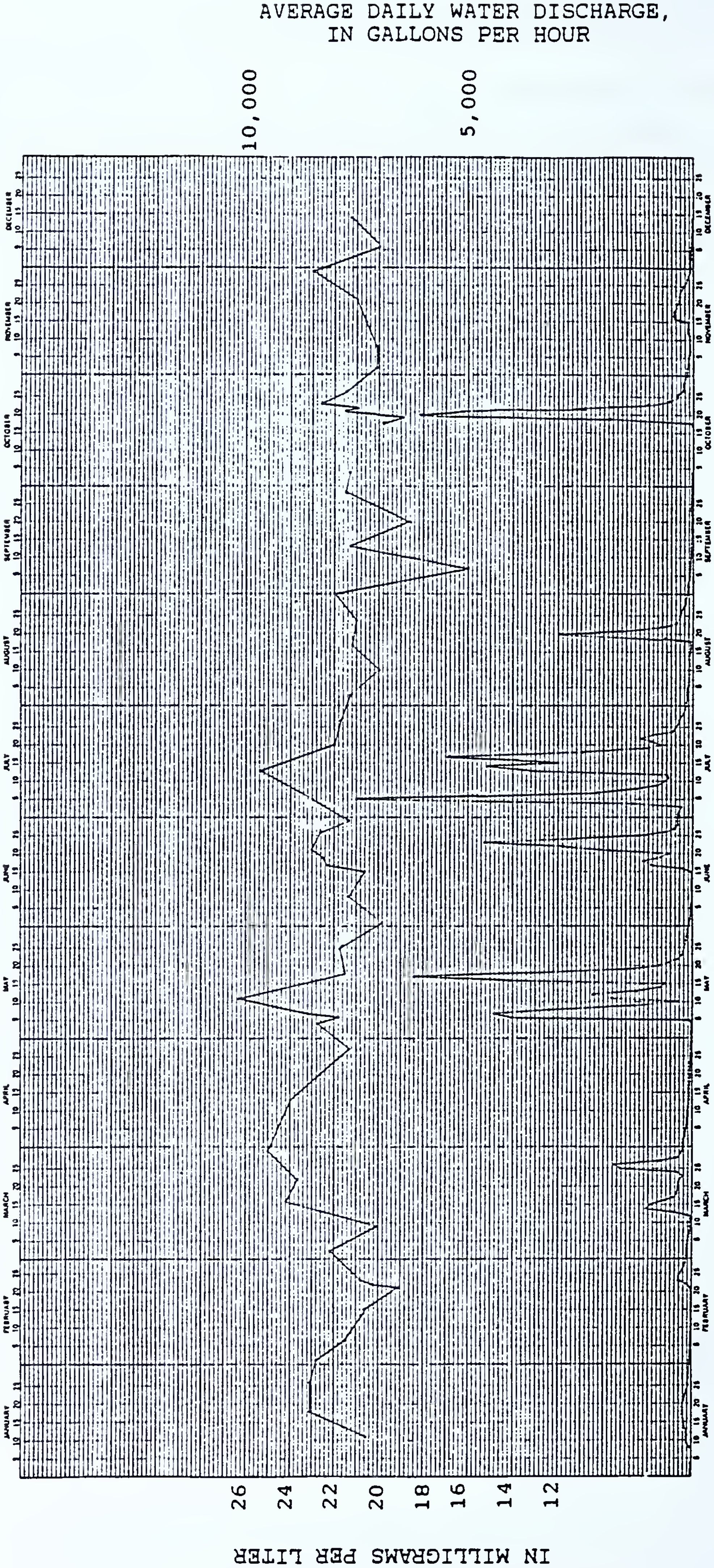

FIGURE 11. 1989 Nitrite plus nitrate concentration and average daily water discharge, Halifax tile drain

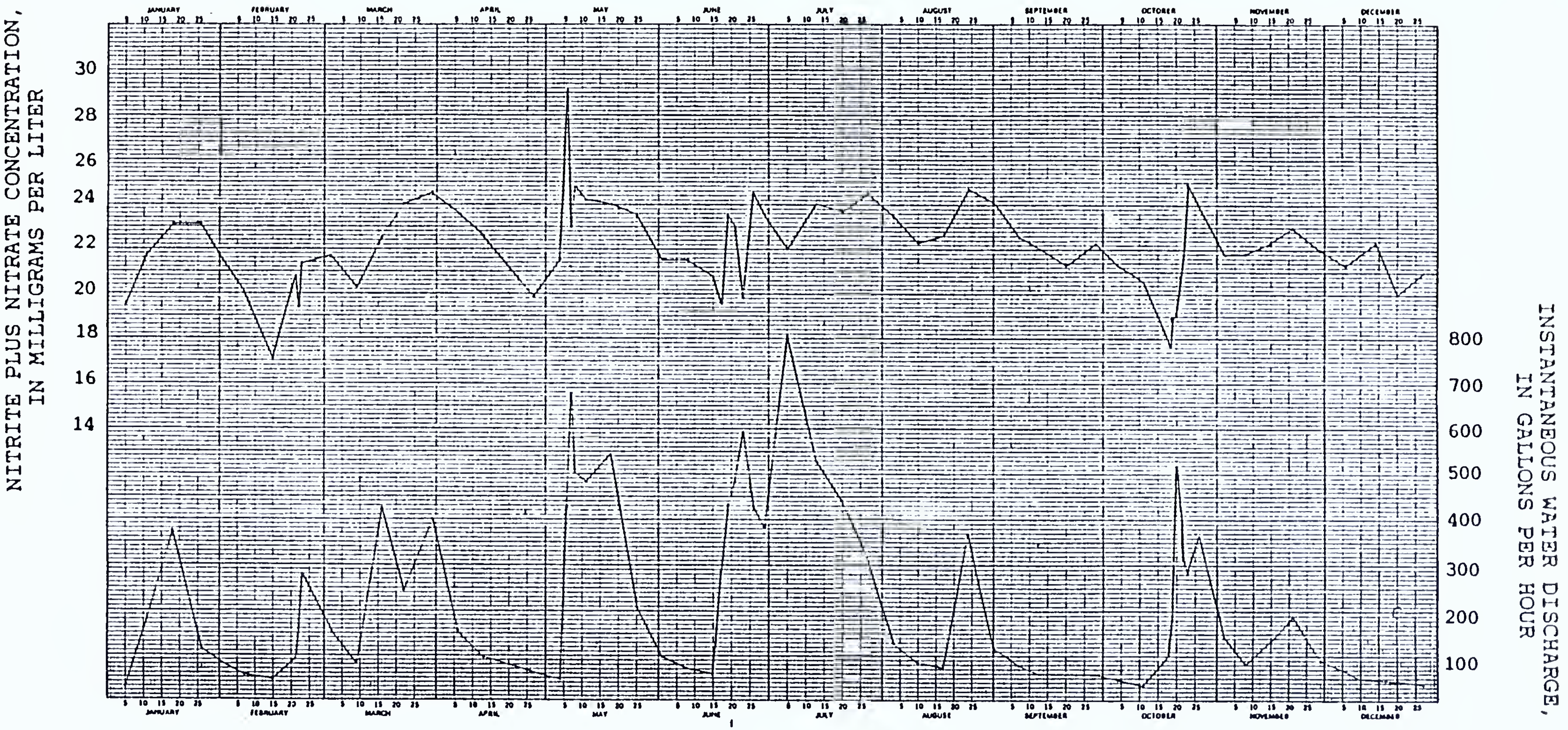

FIGURE 12. 1989 Nitrite plus nitrate concentration and instantaneous water discharge, Halifax spring

Table 4 provides the water-weighted concentrations of nutrients from the Halifax farm. Water-weighted average concentrations of ammonia, kjeldahl nitrogen and total phosphorus were generally higher in the tile drain than in the spring. Kjeldahl nitrogen and total phosphorus concentrations were the highest in surface runoff. Water-weighted concentrations of nitrite plus nitrate were very similar between the tile drain and spring for all years. The annual water-weighted average concentrations were slightly higher in the spring than in the tile drain during 1987 and 1988, and the same in 1989. The water-weighted concentrations in Table 4 and the average measured concentrations for the tile drain (26.2 mg/l in 1987, 19.2 mg/l in 1988, and 21.6 mg/l in 1989) and the spring (22.4 mg/l in 1987, 19.0 mg/l in 1988, and 22.1 mg/l in 1989) are similar. In contrast, the water-weighted concentration in surface runoff was 2.8 times the average measured concentration of 5.8 mg/l. Changes in concentrations in the surface runoff is directly related to water discharge with higher concentrations being sustained by higher flows, while changes in the subsurface water discharge are gradual and small.

Monthly water-weighted concentrations in Table 5 also show a gradual and small change in concentrations in the tile drain and spring, especially in 1987 and 1989. The concentrations are again very similar between the tile drain and the spring, indicating that any water infiltrating the soil enter the water table and eventually is discharged as ground water. For example, wells located in fractured-rock aquifers obtain water from discrete zones or fractures in the well bore. The drilling of monitoring wells at the two farms was stopped as soon as a water-bearing zone was penetrated (Taylor and Edwards, 1989). Thus, most of these wells have only one zone open to the well bore. The zones occur at somewhat random depths below the water table.

TABLE 4. Water-weighted average concentrations of nutrients from the Halifax farm tile drain, spring and surface runoff, September 1987 through December 1989.

Period	Water Discharge 10^3 gallons	Total Ammonia as N	Total Kjeldahl as N	Total Nitrite Plus Nitrate as N	Total Phosphorus as P
		mg/l			
Tile Drain					
Sep - Dec 1987	1,160	0.16	1.02	23.5	0.16
Jan - Dec 1988	602	0.02	0.21	19.9	0.39
Jan - Dec 1989	4,020	0.02	0.29	23.0	0.05
Spring					
Sep - Dec 1987	396	0.02	0.27	24.6	0.02
Jan - Dec 1988	806	0.01	0.15	20.9	0.04
Jan - Dec 1989	1,790	0.01	0.18	22.9	0.05
Surface					
Jan - Dec 1989	632	0.13	1.72	16.1	0.64

TABLE 5. Monthly water-weighted average concentrations of nitrite plus nitrate from Halifax farm tile drain, spring and surface runoff, September 1987 through December 1989.

	Tile Drain			Spring			Surface
	1987	1988	1989	1987	1988	1989	1989
Month	mg/l						
January		21.9	21.9		19.9	22.3	*
February		20.8	21.0		21.3	20.1	*
March		20.2	22.9		20.1	22.9	*
April		19.2	24.2		19.1	23.5	*
May		19.0	24.2		20.3	24.2	*
June		16.1	22.3		19.4	22.1	17.2
July		18.4	24.1		19.1	23.0	19.9
August		12.0	21.1		16.7	24.0	*
September	22.8	*	19.8	22.4	17.4	22.7	*
October	27.1	*	20.8	23.7	20.1	22.9	12.9
November	25.5	21.1	20.7	27.0	20.5	22.5	*
December	22.6	21.2	22.1	22.9	19.2	19.9	10.4

* No flows

Figure 13 shows the relation between the nitrate concentrations in the pumped ground water versus the depth of the water-bearing zone below the water table (Taylor and Edwards, 1989). Note that there is an apparent linear decrease in concentration of nitrate with increasing depth of water-bearing zone. This clearly indicates that the concentration of nitrate is highest at the water table and decreases markedly with increasing depth below the water table.

Table 6 shows the nutrient loads measured from the Halifax farm during the sampling period. The nutrient loads shown for the tile drain and spring for calendar year 1987 are based on the last four months during which water was being discharged. Ammonia, kjeldahl nitrogen and total phosphorus loads were generally higher from the tile drain than from the spring. Total phosphorus load was the highest from surface runoff. The exception was the nitrite plus nitrate loads, when the spring had a higher load in 1988. Calendar year 1988 was a dry year and the spring discharged water throughout the year, while the tile drain stopped flowing for part of the year. Nitrite plus nitrate loads from the tile drain was 96 percent of the total nitrogen load in 1987 and 99 percent of the total nitrogen load in 1988 and 1989. The nitrite plus nitrate load was 99 percent of the total nitrogen load from the spring for all years and 90 percent in the surface runoff. Total phosphorus loads discharged by the total point source discharge was very small.

Table 7 provides the water discharge, annual yields and mean concentrations of the combined subsurface and surface discharges. Nutrient yields were highest in 1989 when the water discharge was the highest. The 23.5 to 120 lbs/ac N loss from the Halifax farm appears to be high when compared to the average annual yield of 33.4 lbs/ac from the Conestoga River watershed (Ott, et. al., 1991). This may be due to the lack of non-farm dilution runoff

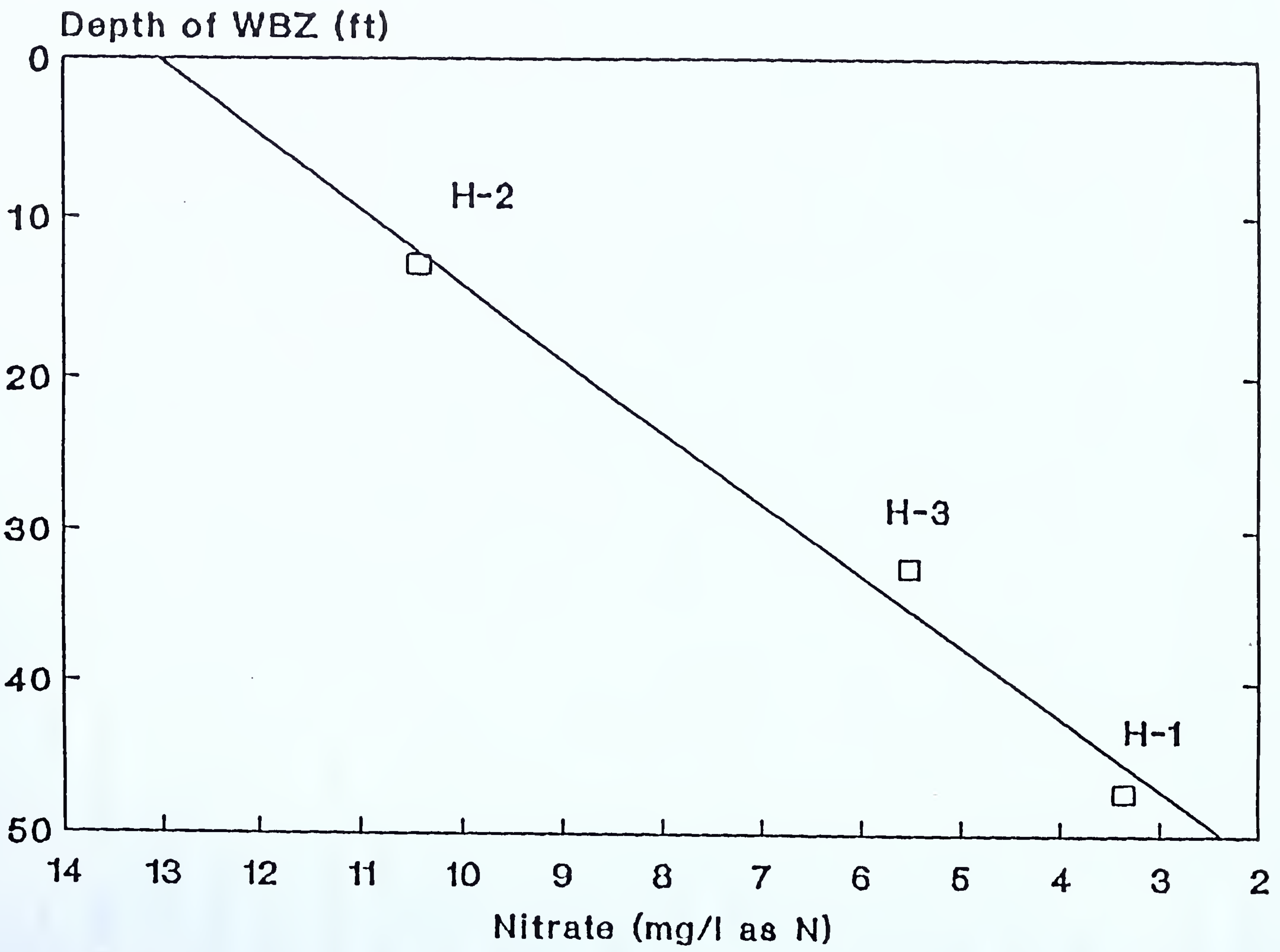

FIGURE 13. Relation of average concentration of nitrate to depth of water-bearing zone below water table.

TABLE 6. Annual nutrient load discharged from the Halifax farm tile drain, spring, and surface flow, and its total point source discharge, September 1987 through December 1989.

Period	Total Ammonia as N	Total Kjeldahl as N	Total Nitrite Plus Nitrate as N	Total Phosphorus as P
	pounds			
Tile Drain				
Sep - Dec 1987	1.51	9.88	227	1.53
Jan - Dec 1988	0.11	1.07	99.8	1.95
Jan - Dec 1989	0.58	9.71	770	1.76
Spring				
Sep - Dec 1987	0.07	0.90	81.3	0.07
Jan - Dec 1988	0.09	1.02	137	0.24
Jan - Dec 1989	0.20	2.76	342	0.70
Surface				
Jan - Dec 1989	0.70	9.08	85.1	3.36
Total Point Source Discharge - Combined Runoff				
Sep - Dec 1987	1.58	10.8	308	1.60
Jan - Dec 1988	0.20	2.09	237	2.19
Jan - Dec 1989	1.48	21.6	1,200	5.82

TABLE 7. Annual water discharge, yields, and mean concentrations of nutrients in combined runoff from the Halifax farm.

		Total Nitrogen		Total Phosphorus	
	Water Discharge	Yield	Mean Concentration	Yield	Mean Concentration
Year	10^3 gal/ac	lbs/ac	mg/l	lbs/ac	mg/l
1987	153	31.3	24.6	0.16	0.12
1988	138	23.5	20.4	0.21	0.19
1989	632	120	22.7	0.57	0.11

experienced in the Conestoga River. The phosphorus yield of 0.1 to 0.19 lb/ac is very small when compared to the average yield of 2.44 lbs/ac from the Conestoga watershed.

Pesticides were applied during spring planting. Water samples were collected for pesticide analysis after application of the pesticides. Table 8 provides a summary of the pesticides applied and detected in the water samples.

TABLE 8. Summary of pesticide application and detection in water samples at the Halifax farm.

Year	Pesticides Applied (Trade Name)	Pesticide Detected (Common Name)		
		Tile Drain	Spring	Surface
		micrograms/liter		
1987	Dual, Bicep	Metolachlor 0.58	Metolochlor 0.67	
		Atrazine 2.5	Atrazine 2.3	
	Gramoxone	Not Detected	Not Detected	
	Pounce	Not Detected	Not Detected	
1988	Dual	Metolachlor 0.59	Not Detected	
	Extrazine	Atrazine 0.19	Not Detected	
	2-4D, Banvel	Not Detected	Not Detected	
	Gramoxone	Not Detected	Not Detected	
1989		Metolachlor 1.8	Not Detected	Metolachlor 2.7
	Extrazine	Atrazine 1.1	Atrazine 1.6	Not Detected
	Bladex	Cyanazine 0.55	Cyanazine 1.0	Cyanazine 2.4
	Pounce	Not Detected	Not Detected	Not Detected
	Lorox	Not Detected	Not Detected	Not Detected

Not Detected means: Atrazine = <0.2 ug/l; cyanozine = <0.2 ug/l;
Motolochlor =<0.1 ug/l; 2,4-D = <0.4 ug/l.

Enterline Farm

1987

Measured nitrite plus nitrate concentrations from the tile drain range from 0.5 mg/l to 26.5 mg/l with an average concentration of 5.9 mg/l and a median of 6.8 mg/l. Figure 14 shows the concentration of nitrite plus nitrate plotted against time along with the corresponding water discharge. A slightly increasing trend is evident from the graph and is also shown by the seasonal average of 5.5 mg/l during July through September and 9 mg/l during the October through December period. Total phosphorus concentrations averaged from 0.01 mg/l to 1.65 mg/l with an average concentration of 0.25 mg/l and a median of 0.07 mg/l.

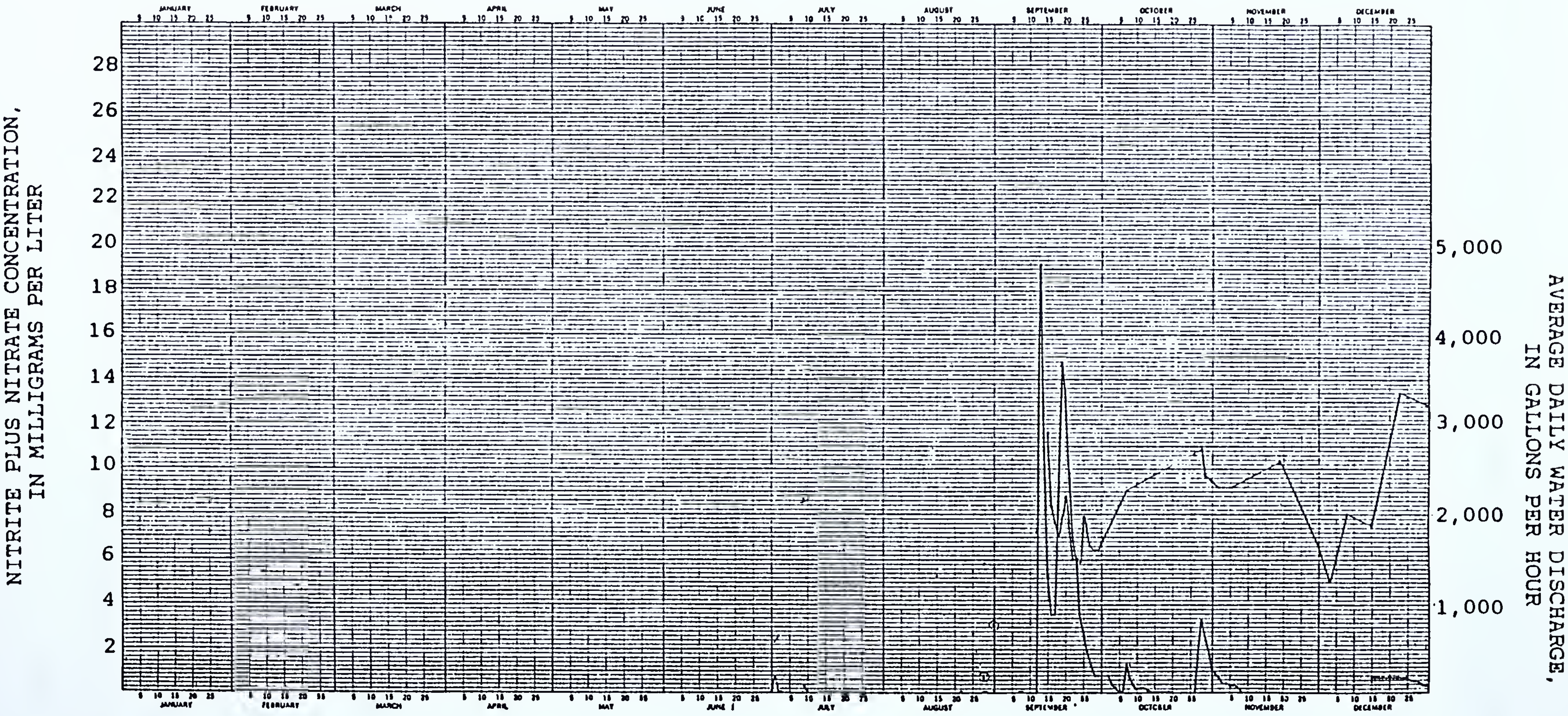

FIGURE 14. 1987 Nitrite plus nitrate concentration and average daily water discharge, Enterline tile drain

1988

Measured nitrite plus nitrate concentrations in the tile drain ranged from 6.16 mg/l to 53.0 mg/l with an average of 11.33 mg/l and a median of 8.47 mg/l. The nitrite plus nitrate concentrations plotted in Figure 15 show an increasing trend in the first five months of the year, with the highest concentrations occurring during spring planting, and the lowest water discharge. The highest concentration, occurring about May 17, was the result of heavy rains occurring after fertilizer application. Spillage of excess fertilizer occurred along the edges of the field just prior to the rain. The tile drain stopped flowing by the end of May. Total phosphorus concentrations ranged from 0.2 mg/l to 1.76 mg/l with an average of 0.21 mg/l and a median of 0.04 mg/l.

1989

Measured nitrite plus nitrate concentrations ranged from 0.9 mg/l to 25.4 mg/l with an average of 12.5 mg/l and a median of 10.2 mg/l. Figure 16 shows sporadic occurrences of water discharge with high nitrite plus nitrate concentrations in the beginning of the year and gradual decreases in concentration as the water discharge increases. Total phosphorus concentration ranged from 0.02 mg/l to 0.19 mg/l with an average of 0.03 mg/l and median of 0.03 mg/l.

Surface water was measured for the first time in 1989 and the measured nitrite plus nitrate concentrations ranged from 0.04 mg/l to 14.3 mg/l with an average of 5.47 mg/l and a median of 5.15 mg/l.

It was previously stated that the tile drain system at the Enterline farm is located at a depth that is above the water table most of the time and flows only during and following precipitation events. Taylor and Edwards

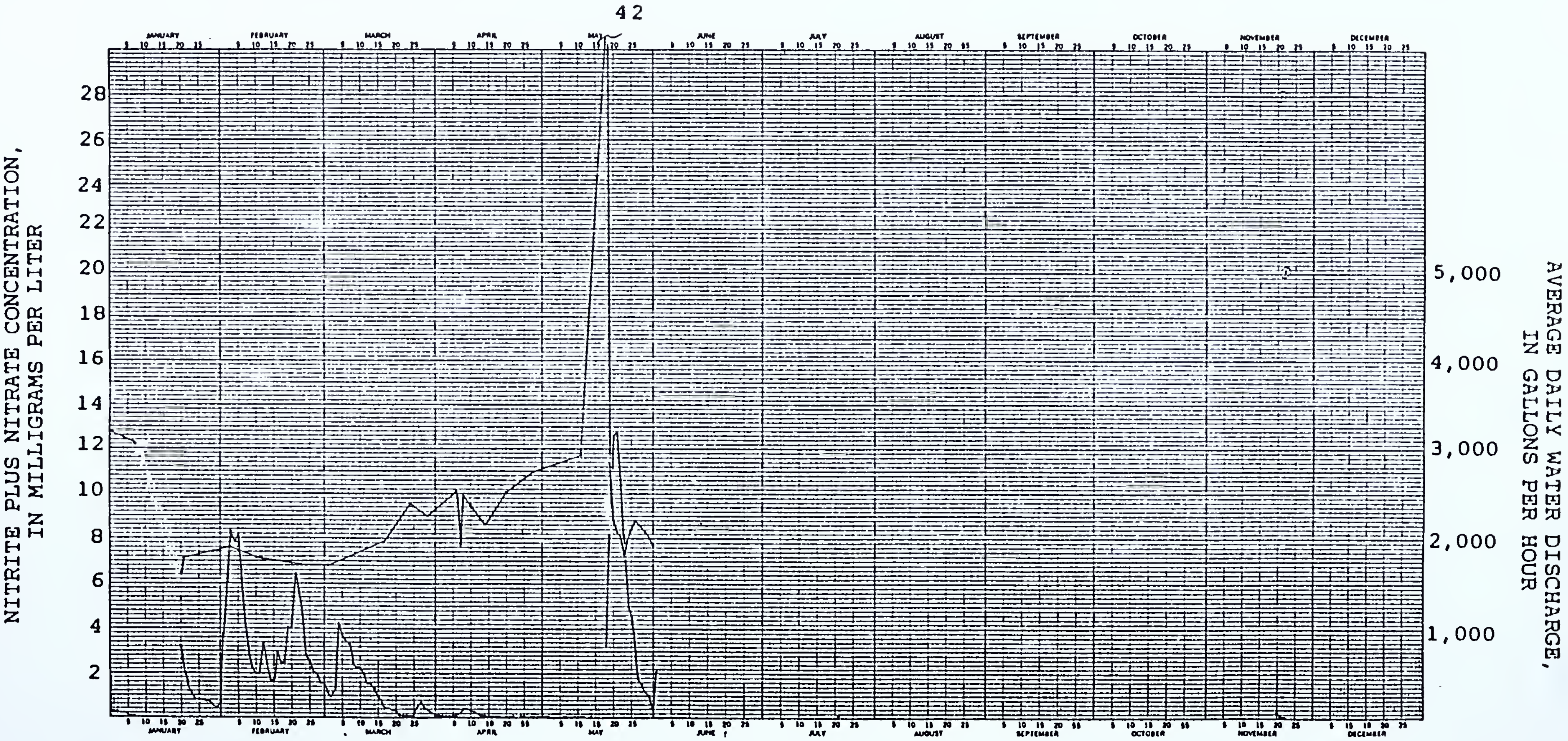

FIGURE 15. 1988 Nitrite plus nitrate concentration and average daily water discharge, Enterline tile drain

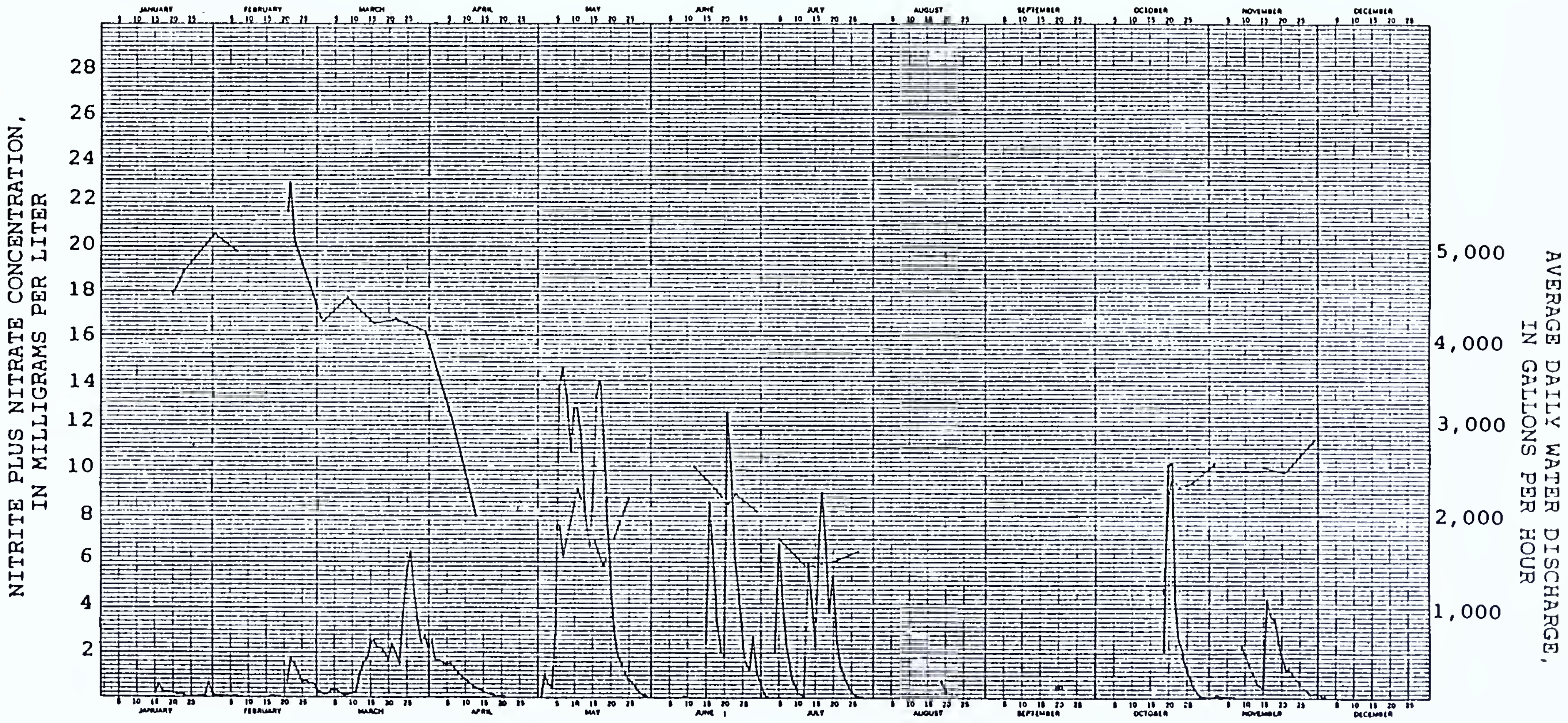

FIGURE 16. 1989 Nitrite plus nitrate concentration and average daily water discharge, Enterline tile drain

(1989) commented on the very high initial nitrate concentration during the significant storm in May 1988, which diminished rapidly to a fairly constant level approximately the same as in ground water. This rapid change was reported to correspond with a change in the primary source of water to the tile drain from surface water to ground water as the storm progressed and the ground-water level rose.

Table 9 shows the water-weighted average concentrations of nutrients from the Enterline farm. The water-weighted average concentrations of ammonia, kjeldahl nitrogen and total phosphorus generally decreased as water discharge increased. The high concentration of ammonia in 1988 was probably the result of heavy rainfall very shortly after urea was applied to the fields in May. The tile drain stopped flowing after that storm event. Water-weighted average concentration of nitrite plus nitrate was slightly lower in 1988 when water discharge was lowest. Commercial fertilizer application was also lower in 1988. The concentration increased in 1989 when fertilizer was not applied and water discharge increased. The water-weighted average annual nitrite plus nitrate concentration appears to level off at around 8-9.5 mg/l each year. This concentration is quite similar to the average concentration of well H2 of 10.4 mg/l reported by Taylor and Edwards (1989). Well H2 has the shallowest water-bearing zone and water produced from this well approximates the quality of the shallow ground water in the basin.

Surface water, measured for the first time in 1989, had a water-weighted concentration of nitrite plus nitrate of 3.99 mg/l.

Monthly water-weighted concentrations of nitrite plus nitrate are shown in Table 10. The concentrations vary considerably as contrasted to the Halifax farm. The discharge from the Enterline farm is a mixture of surface water entering the gravel inlet connected to a tile drain, water infiltrating

TABLE 9. Water-weighted average concentrations of nutrients from the Enterline farm tile drain and surface runoff, July 1987 through December 1989.

Period	Water Discharge 10^3 gallons	Total Ammonia as N	Total Kjeldahl as N	Total Nitrite Plus Nitrate as N	Total Phosphorus as P
		mg/l			
		Tile Drain			
Jul - Dec 1987	2,050	0.04	0.31	9.00	0.08
Jan - Dec 1988	1,430	0.16	0.30	8.19	0.22
Jan - Dec 1989	2,850	0.01	0.24	9.43	0.04
		Surface			
Jan - Dec 1989	584	0.03	0.47	3.99	0.09

Table 10. Monthly water-weighted average concentrations of nitrite plus nitrate from the Enterline farm tile drain and surface runoff, July 1987 through December 1989

	Tile Drain			Surface
	1987	1988	1989	1989
Month	mg/l			
January		7.41	16.5	*
February		7.26	22.3	*
March		7.03	16.8	*
April		9.41	14.0	*
May		10.12	7.84	*
June		*	9.05	9.88
July	10.4	*	6.18	3.92
August	2.66	*	6.19	*
September	8.72	*	5.99	*
October	9.29	*	6.59	0.33
November	9.73	34.17	10.3	*
December	7.08	*	12.0	*

* No flow

through the soil and, at times, shallow ground water as the water table rises to levels affecting the drain; whereas, the source of water at the Halifax farm is primarily ground water. The concentrations in the surface runoff also varied considerably.

Table 11 provides the nutrient loads from the tile drain, surface discharge and total point source discharge. Nutrient loadings were the highest in 1989, which was the wettest year. Total phosphorus loads discharge by the tile drain and surface runoff were very small.

Table 12 provides a comparison of total nitrogen and total phosphorus yield and water-weighted concentrations based on the total drainage area and on the area planted in corn only.

It was assumed that the total nitrogen and total phosphorus contribution from the wooded area was negligible; therefore, the total measured nitrogen and total phosphorus loads came from the corn fields only. Water discharge was prorated on a per acre basis in order to compute the water-weighted concentrations. The table shows that the yields and mean concentrations nearly double when computed on the corn acreage only and probably better represents the response to the agronomic practices. The concentrations based on the total drainage area show the dilution affect of the non-farmed area. The adjusted concentrations are lower than the mean concentrations shown in Table 7 for the Halifax farm.

The 4.1 to 10.2 lbs/ac of total nitrogen yield is very similar to the average annual total nitrogen yield reported for other Susquehanna River subbasins that are at least 50 percent forested (Ott, et. al., 1991). The total phosphorus yields are much lower than reported for the other Susquehanna River subbasins.

TABLE 11. Annual nutrient load discharged from the Enterline farm tile drain and surface flow, and its total point source discharge, July 1987 through December 1989.

Period	Total Ammonia as N	Total Kjeldahl as N	Total Nitrite Plus Nitrate as N	Total Phosphorus as P
	pounds			
Tile Drain				
Jul - Dec 1987	0.70	5.26	154	1.39
Jan - Dec 1988	1.85	3.55	97.7	2.63
Jan - Dec 1989	0.33	5.63	224	0.94
Surface				
Jan - Dec 1989	0.17	2.30	19.4	0.46
Total Point Source Discharge - Combined Runoff				
Jul - Dec 1987	0.70	5.26	154	1.39
Jan - Dec 1988	1.85	3.55	97.7	2.63
Jan - Dec 1989	0.50	7.93	243	1.40

TABLE 12. Comparison of annual water discharge, yields, and mean nutrient concentrations between the total drainage area (24.63 acres) and the corn area (12.57 acres) at the Enterline farm.

		Total Nitrogen		Total Phosphorus	
	Water Discharge	Yield	Mean Concentration	Yield	Mean Concentration
Year	10^3 gal/ac	lbs/ac	mg/l	lbs/ac	mg/l
Total Drainage Area (24.63 acres)					
1987	83.1	6.45	9.30	0.06	0.08
1988	58.1	4.11	8.48	0.11	0.22
1989	139	10.2	8.79	0.06	0.05
Corn Area (12.57 acres)					
1987	83.1	12.6	18.2	0.11	0.16
1988	58.1	8.05	16.6	0.21	0.43
1989	139	20.0	17.2	0.11	0.09

Pesticides were applied during spring planting. Water samples were collected for pesticide analysis after application of the pesticides. Table 13 provides a summary of the pesticides applied and detected in the water samples.

TABLE 13. Summary of pesticide application and detection in water samples at the Enterline farm.

Year	Pesticides Applied (Trade Name)	Pesticide Detected (Common Name)			
		Tile Drain		Surface	
		mg/l			
1987	Bicep	Metolachlor	9.2		
		Atrazine	12.0		
	Bladex	Cyanazine	10.0		
	Lorox	Not Detected			
	Furadan	Not Detected			
1988	None Applied	Metolachlor	1.2		
		Atrazine	1.7		
		Cyanazine	1.3		
1989	None Applied	None Detected		Metolachlor	0.10

Not Detected means: Atrazine = <0.2 ug/l; cyanozine = <0.2 ug/l;
Motolochlor =<0.1 ug/l; 2,4-D = <0.4 ug/l.

NUTRIENT ACCOUNTABILITY

Halifax Farm

1987

Water discharge data in Table 14 show that for the last four months of 1987 the tile drain discharged an equivalent of 21 percent of the precipitation, while the spring discharged 7 percent.

TABLE 14. Halifax Farm, 1987

	Water Discharge					Nitrogen					Phosphorus				
	Precipitation	Tile Drain	Spring	Surface	Total Discharge	Manure/ Fertilizer	Tile Drain	Spring	Surface	Total Nitrogen Load	Manure/ Fertilizer	Tile Drain	Spring	Surface	Total Phosphorus Load
						Input	Output				Input	Output			
Month	10^3 gallons					pounds									
January						280*					123*				
February															
March						407**									
April															
May															
June						1,290**					94**				
July															
August															
September	3,620	693	5.90	--	699		141	1.13	--	133		1.43	.00	--	1.43
October	703	19.2	76.9	--	96	159*	4.48	15.5	--	19.5	56*	.01	.01	--	.02
November	910	275	151	--	426		59.0	34.4	--	92.3		.06	.03	--	.09
December	368	173	159	--	332		32.8	30.6	--	62.9		.04	.03	--	.07
Annual	5,600	1,160	396	--	1,550	2,140	237	81.6	--	319	273	1.54	.07	--	1.61
Crop Uptake										1,380					251
TOTAL						2,140				1,700	273				253
Excess/ Deficit										+ 440					+ 20

* Manure
** Fertilizer

NOTE: January manure applied in fall of 1986

Manure provided 14 percent of the N input during the growing season, while providing 57 percent of the phosphorus input. The N and P uptake by the rye haylage and corn silage accounted for 70 percent and 116 percent of the combined respective N and P input. This obviously does not include the nutrients applied in the October manure application.

The nutrient removal by the combined tile drain and spring discharge was 15 percent and 0.6 percent of the N and P input, respectively, and 19 percent and 0.6 percent of the N and P output, respectively.

1988

Water discharge data in Table 15 show that, for the relatively dry year, the tile drain discharged an equivalent of only 7 percent of the precipitation, while the spring discharged 9 percent.

The nitrogen input for 1988 includes 440 pounds from 1987. This is assumed to be carryover or residual. Spring soil analyses for the fields indicated the soils contained an average of 45 lbs/ac nitrate-nitrogen. This calculates to a residual of 458 pounds for the 10.19 drainage area, a value similar to the calculated excess for 1987.

Manure (primarily 1987 fall application) provided 17 percent of the growing season N input, while providing 15 percent of the P input. The N and P uptake by the rye haylage and corn silage accounts for 103 percent and 133 percent of the combined respective N and P growing input.

The nutrient removal by the combined tile drain and spring discharge was 22 percent and 1 percent of the N and P input, respectively, and 18 percent and 1 percent of the N and P output, respectively.

TABLE 15. Halifax Farm, 1988

	Water Discharge					Nitrogen					Phosphorus				
	Precip-itation	Tile Drain	Spring	Surface	Total Discharge	Manure/ Fertilizer	Tile Drain	Spring	Surface	Total Nitrogen Load	Manure/ Fertilizer	Tile Drain	Spring	Surface	Total Phosphorus Load
						Input	Output				Input	Output			
Month	10^3 gallons					pounds									
January	501	56.5	40.7	0	97.2	440 #	10.5	6.8	0	17.2	36#	1.52	.01	0	1.53
February	703	68.4	246	0	314	22*	12.0	44.3	0	55.6	19	.12	.07	0	.19
March	515	120	110	0	230	129**	20.3	19.3	0	39.4		.02	.03	0	.05
April	484	23.7	25.8	0	49.5	0	3.9	4.2	0	8.0		.01	.00	0	.01
May	1,360	153	122	0	275	47**	24.4	20.8	0	45.0	62**	.06	.03	0	.09
June	479	52.6	56.7	0	109	35**	7.1	9.3	0	16.2	46**	.18	.01	0	.09
July	955	13.2	28.4	0	41.6	354**	2.0	4.5	0	6.4		0	.01	0	.01
August	870	.156	17.5	0	17.7		0	2.5	0	2.5		0	.02	0	.02
September	941	0	13.3	0	13.3		0	1.9	0	1.9		0	.00	0	.00
October	507	0	4.31	0	4.31		0	0.7	0	0.7		0	.00	0	.00
November	1,100	96.8	106	0	203	1,780***	17.5	18.1	0	35.2	1,350***	.05	.03	0	.08
December	280	17.9	35.6	0	53.5		3.2	5.8	0	9.0		0	.01	0	.01
Annual	8,700	602	806	0	1,410	1,070~	101	138	0	239		1.96	.22	0	2.18
Crop Uptake										1,080					217
TOTAL						1,070				1,320	163				219
Excess/ Deficit															

* Manure
** Fertilizer
*** Value minus water load loss will be carried as residual to 1989
~ Input is composed of growing season input plus 44 pounds lost in November/December point source output from fall manure application
# Residual, as indicated from Spring soil test

NOTE: 1,780 - (44 lost in November plus December) = 1,740 residual for 1989

1989

Water discharge data in Table 16 show that for the tile drain discharged an equivalent of 31 percent of the precipitation, while the spring discharged 14 percent, and surface runoff 5 percent. This achieves, for this relatively wet year, a point source discharge equivalent to 50 percent of the precipitation total.

A high residual of 1,740 pounds N and 1,350 pounds P was carried over from 1988 fall manure applications. Spring soil tests indicated nutrient levels of 662 pounds nitrate nitrogen and 32 pounds orthophosphate.

Manure supplied 83 percent of the N input and 100 percent of the P input for the growing season. The N and P uptake by the rye haylage, sudex,and corn silage accounted for 49 percent and 20 percent of the combined respective N and P input.

The nutrient removal by the combined tile drain, spring and surface discharge was 42 percent and 0.4 percent of the N and P input, respectively, and 46 percent and 2 percent of the N and P output, respectively.

	Water Discharge					Nitrogen					Phosphorus				
Month	Precip-itation	Tile Drain	Spring	Surface	Total Discharge	Manure/ Fertilizer	Tile Drain	Spring	Surface	Total Nitrogen Load	Manure/ Fertilizer	Tile Drain	Spring	Surface	Total Phosphorus Load
						Input	Output				Input	Output			
	10^3 gallons					pounds									
January	435	81.7	127	0	209	1,740 #	15.0	23.7	0	38.6	1,350 #	0.03	0.03	0	.06
February	443	48.7	75.8	0	125		8.6	13.1	0	21.7		.03	.02	0	.05
March	728	300	175	0	475		57.4	33.3	0	90.4		.08	.05	0	.13
April	305	64.5	112	0	177	408**	13.2	22.0	0	35.1		.02	.02	0	.04
May	2,310	927	279	0	1,210		189	56.6	0	243		.30	.13	0	.43
June	1,960	476	181	49.0	706	111*	89.9	33.7	7.5	130	82	.17	.09	0.10	.17
July	2,620	1,230	385	307	1,920	95.0*	250	74.7	54.1	374	42	.86	.26	1.36	2.48
August	1,090	233	128	0	361		41.2	25.8	0	66.6		.07	.03	0	.10
September	919	39.6	54.1	0	93.7		6.7	10.3	0	16.8		.01	.01	0	.02
October	1,360	455	129	153	737	510**	80.7	24.7	17.5	121		.15	.03	0.67	.85
November	531	144	103	0	247		25.1	19.4	0	44.2		.04	.02	0	.06
December	277***	17.4	43.5	123	184		3.2	7.2	15.0	25.2		.00	.01	1.26	1.27
Annual	12,700	4,020	1,790	632	6,440	2,860	780	345	94.1	1,210	1,470	1.76	.70	3.29	5.70
Crop Uptake										1,410					286
TOTAL						2,860				2,620	1,470				292
Excess/ Deficit										+ 240					+ 1,180

* Manure
** Fertilizer
*** Estimate
# Residual

Enterline Farm

1987

Water discharge data in Table 17 show that for the last six months of 1987 the tile drain discharged an equivalent of 11 percent of the precipitation. The input of 1,690 pounds N and 290 pounds P was derived solely from commercial fertilizer. The N and P uptake by the corn grain accounted for 63 percent and 37 percent of the respective N and P input. The six month nutrient removal by the tile drain discharge was 9 percent and 0.5 percent of the respective N and P input.

The point source discharge equated to slightly more than 10 percent of the precipitation falling on the drainage area and carried slightly less than 10 percent of the N input and less than 1 percent on the P input.

1988

Water discharge data in Table 18 show that the tile drain discharged an equivalent of 6.5 percent of the annual precipitation.

The residual plus the input of 1,540 pounds N and residual plus 132 pounds P accounted for the availability of 2,060 pounds N and 156 pounds P. The N and P uptake by the corn grain accounted for 11 percent and 15 percent of the available N and P, respectively.

The nutrient removal by the tile drainage discharge was 5 percent and 1.5 percent of the N and P input, respectively.

The point source nutrient discharge, which equated to slightly more than 6 percent of the annual drainage area precipitation accounted for 5 percent of the N input and 1.5 percent of P input.

TABLE 17. Enterline Farm, 1987

Month	Water Discharge				Nitrogen				Phosphorus			
	Precip- itation	Tile Drain	Surface	Total Discharge	Fertilizer	Tile Drain	Surface	Total Nitrogen Load	Fertilizer	Tile Drain	Surface	Total Phosphorus Load
					Input	Output			Input	Output		
	10^3 gallons				pounds							
January												
February												
March												
April												
May					1,690				290			
June												
July	1,970	7.39	--	7.39		0.68	--	0.68		0.03	--	0.03
August	2,620	.926	--	.926		0.03	--	0.03		0.01	--	0.01
September	7,010	686	--	686		52.78	--	52.78		0.97	--	0.97
October	2,030	96.9	--	96.9		7.97	--	7.97		0.02	--	0.02
November	3,040	969	--	969		80.18	--	80.18		0.18	--	0.18
December	1,200	287	--	287		17.21	--	17.21		0.19	--	0.19
Annual	17,900	2,050	--	2,050		158.85	--	158.85		1.40	--	1.40
Crop Uptake								1,060				106
TOTAL					1,690			1,220	290			107

TABLE 18. Enterline Farm, 1988

	Water Discharge				Nitrogen				Phosphorus			
	Precip- itation	Tile Drain	Surface	Total Discharge	Fertilizer	Tile Drain	Surface	Total Nitrogen Load	Fertilizer	Tile Drain	Surface	Total Phosphorus Load
					Input	Output			Input	Output		
Month	10^3 gallons				pounds							
January	903	87.1	0	87.1	515 #	5.53	0	5.53	24 #	1.04	0	1.04
February	1,830	654	0	654		40.99	0	40.99		0.97	0	0.97
March	1,420	225	0	225		13.47	0	13.47		0.02	0	0.02
April	1,460	20.1	0	20.1		1.63	0	1.63		0.01	0	0.01
May	4,190	442	0	442	1,540	39.04	0	39.04	132	0.30	0	0.30
June	1,020	0	0	0		0	0	0		0	0	0
July	2,540	0	0	0		0	0	0		0	0	0
August	1,670	0	0	0		0	0	0		0	0	0
September	2,000	0	0	0		0	0	0		0	0	0
October	1,510	0	0	0		0	0	0		0	0	0
November	2,940	2.43	0	2.43		0.56	0	0.56		0.00	0	0.00
December	749	0	0	0		0	0	0		0	0	0
Annual	22,100	1,430	0	1,430	2,060	101.22	0	101.22	156	2.34	0	2.34
Crop Uptake								229				22.9
TOTAL					2,060			330	156			25.2

Residual based on soil analysis

1989

Water discharge data in Table 19 show that the tile drain discharged an equivalent of 10 percent of the annual drainage area precipitation, while the surface discharge amounted to 2 percent.

Fertilizer was not applied in 1989. Rye was seeded, mowed in the summer, and left to decompose in the field.

The nutrient removal by the combined tile drain and surface discharge as 37 percent and 10 percent of the N and P soil residual.

The fall 1989 soil analysis indicated that the residual soil N had decreased from 55 lbs/ac in the spring to 17 lbs/ac in the fall, while the residual soil P had decreased from 1.1 lbs/ac in the spring to 0.2 lbs/ac in the fall.

The point source nutrient discharge, which equated to just less than 10 percent of the annual drainage area precipitation, accounted for 37 percent of the soil residual N and 10 percent of the residual P.

SOIL NITROGEN STATUS - HALIFAX FARM

The following soil nitrogen status table (Table 20) is an attempt to see how well the monitored Halifax drainage basin behaves as a closed system. Since monitoring of the tile drain and spring didn´t start until September 1987, the eight months nitrogen loss through the tile drain and spring are unknown; therefore, a reasonable soil status is assumed with the spring 1988 soil analysis. The soil status is again adjusted with the spring 1989 soil analysis. The figures appear reasonable when considering that they represent 10.19 acres of drainage area.

TABLE 19. Enterline Farm, 1989

	Water Discharge				Nitrogen				Phosphorus			
	Precip-itation	Tile Drain	Surface	Total Discharge	Fertilizer	Tile Drain	Surface	Total Nitrogen Load	Fertilizer	Tile Drain	Surface	Total Phosphorus Load
					Input	Output			Input	Output		
Month	10^3 gallons				pounds							
January	1,100	20.5	0	20.5	690 #	2.78	0	2.78	14 #	0.00	0	0
February	1,450	46.2	0	46.2		8.68	0	8.68		0.01	0	0.01
March	2,530	346	0	346		48.73	0	48.73		0.06	0	0.06
April	716	107	0	107		12.51	0	12.51		0.02	0	0.02
May	6,670	1,090	0	1,090		73.23	0	73.23		0.36	0	0.36
June	5,390	412	171	583		32.15	14.82	46.97		0.10	0.16	0.26
July	4,680	417	141	558		22.53	5.02	27.55		0.21	0.07	0.28
August	2,080	5.8	0	5.8		0.31	0	0.31		0.00	0	0
September	2,270	2.7	0	2.7		0.15	0	0.15		0.00	0	0
October	3,630	211	271	482		12.34	1.85	14.19		0.12	0.24	0.36
November	2,030	191	0	191		16.42	0	16.42		0.05	0	0.05
December	689	0.4	0	0.4		0.04	0	0.04		0.00	0	0
Annual	33,200	2,850	584	3,430	690	230	21.69	252	14	0.94	0.46	1.40
Crop Uptake								--				--
TOTAL					690			252	14			1.4

Residual based on soil analysis

TABLE 20. Soil nitrogen status, Halifax farm.

	1987				1988				1989			
	N Input	N Output		Soil N Status	N Input	N Output		Soil N Status	N Input	N Output		Soil N Status
Month		Crop	Water			Crop	Water			Crop	Water	
	pounds											
January	280		?				17	( )			39	1,454
February			?		22		56	( )			22	1,432
March	407		?	(687)	129		39	( )			90	1,342
April			?				8	440*	408		35	1,715
May		487	?	(200)	47	180	45	262		539	243	662*
June	1,290		?	(1,490)	35		16	281	111		130	643
July			?	(1,490)	354		6	629	95		374	364
August			?	(1,490)			3	626			67	297
September		891	133	(466)			2	624			17	280
October	159		20	(605)		866	1	- 243	510	730	121	- 61
November			92	(513)	1,780		35	1,502			44	- 105
December			63	(450)			9	1,493			25	- 130

* Soil analysis

It is of interest to note that approximately the same amount of N was removed by the point source discharge as by the two crops. Also, looking back at 1987 data, crop N removal was higher than in 1989, with a somewhat lower N input.

SUMMARY AND CONCLUSIONS

There are numerous tile drains installed on farms in the Susquehanna River basin which are, in effect, point sources of nutrient discharge. Little is known about the quality of these discharges. Therefore, it is important that these discharges are characterized so that the effect of these point source discharges can be evaluated.

A study was conducted on two farms to:

a) Provide an indication of the quality and quantity of the nutrient discharge from agricultural tile drainage systems which drain two dissimilar farming operations. One is an upland 150 head dairy farm (Clugston/Halifax farm) which grows its own grain, hay, and silage and fertilizes primarily with dairy manure and supplements with commercial fertilizer. The second farm (Harmon/Enterline farm) is primarily a lowland corn producing site that uses only commercial fertilizer. The quantity of discharge from the two tile drain systems was monitored continuously while the nutrient chemistry was monitored periodically during both non-storm and storm periods.

b) Calculate a partial cropland nutrient budget primarily for the dairy farm. This was accomplished by determining the nutrient input, output and storage. Nutrient input was determined by combining data concerned with the quality and quantity of manure and commercial fertilizers applied to the fields. The output was determined by measurement of the: 1) crop yield and its nutrient content; 2) quantity of tile drain, and where appropriate, spsring discharge and its nutrient content; and 3) quantity of surface runoff and its nutrient content. Storage was determined from soil nutrient data.

Halifax Farm

Precipitation occurring during the sample collection period at the Halifax farm was 20.3 inches for the last four months of 1987, 31.4 inches in 1988, and 46.9 inches in 1989. The normal precipitation for the area is 41.4 inches.

Point source water discharge from the tile drain and spring the last four months of 1987 was 1,560 x 10^3 gallons or 28 percent of the precipitation for the same period. There was a significant overland runoff event in September, 1987, which was not measured. Water discharge measured in 1988 was 1,410 x 10^3 gallons or 16.2 percent of the precipitation. Precipitation was 10 inches below normal and, therefore, resulted in no overland runoff events in 1988. The tile drain flow was minimal in August and stopped flowing in September and October. The spring flowed all year and had a higher discharge than the tile drain. The combined water discharge measured in 1989 was 6,440 x 10^3 gallons or 49.5 percent of the precipitation in 1989. The tile drain accounted for the greatest portion of the point source water discharge in both 1987 and 1989, the wetter years.

The tile drain and spring at Halifax normally flow continuously, indicating that the tile drain is located below the water table and, therefore, is a collection point for the shallow, most contaminated, groundwater. The spring is also a collection point. Thus, most of the nutrient contaminated shallow ground water is captured by the drain and spring and only the deeper, much less contaminated ground water, bypasses the tile drain and spring.

The average measured nitrite plus nitrate concentrations in the Halifax tile drain were very similar to those measured in the spring. The average measured concentrations in the tile drain was 26.2 mg/l in 1987, 19.2 mg/l in 1988, and 21.6 mg/l in 1989, while the average measured concentrations in the spring were 22.4 mg/l in 1987, 19.0 mg/l in 1988 and 22.1 mg/l in 1989. The measured nitrite plus nitrate concentrations in overland runoff, measured for the first time in 1989, averaged 5.89 mg/l. The water-weighted average concentrations for the tile drain and spring were very similar to the measured average concentrations. In contrast, the water-weighted concentration in the overland runoff was 2.8 times the average measured concentration. Changes in concentration in surface runoff occur rapidly with higher concentrations being sustained by higher flows, while changes in ground water concentrations are gradual and small.

Measured concentrations of total phosphorus in the tile drain averaged 0.16 mg/l in 1987, 0.2 mg/l in 1988, and 0.04 mg/l in 1989, as compared to 0.03 mg/l in 1987, 0.04 mg/l in 1988, and 0.02 mg/l in 1989 for the spring.

Total loads of nitrite plus nitrate were 308 pounds in the last four months of 1987, 237 pounds in 1988, and 1,200 pounds in 1989. The tile drain accounted for 227 pounds in 1987, 99.8 pounds in 1988, and 770 pounds in 1989. Loads from the spring were 81.3 pounds in 1987, 137 pounds in 1988, and 342 pounds in 1989. Surface runoff accounted for 85.1 pounds. Total phosphorus loads from the Halifax farm were 1.60 pounds in 1987, 2.19 pounds in 1988, and 5.82 pounds in 1989. Surface runoff accounted for 3.36 pounds of total phosphorus in 1989. Annual nutrient loads varied directly with water charge.

Results of pesticides analyses in water samples generally reflected the pesticides applied on the Halifax farm.

Nutrient accountability computations for the Halifax farm show a reasonable balance for nitrogen input and output, but an excess in phosphorus input. Manure application rates are set to meet the nitrogen requirements, thus, excess phosphorus is probably being applied. Phosphorus loadings measured in the tile drain, spring and surface runoff are very small; therefore, the phosphorus content in the soil is being built up. A soil nitrogen status was computed to attempt to see how well the monitored Halifax farm drainage basin behaves as a closed system. The figures appear reasonable when considering that they represent 10.19 acres.

Enterline farm

Precipitation at the Enterline farm was 26.7 inches for the last six months of 1987, during which samples were collected, 33.5 inches in 1988 and 49.7 inches in 1989.

Point source water discharge measured for the last six months of 1987 was 2,050 x 10^3 gallons or 11.4 percent of precipitation for the same period, 1,430 x 10^3 gallons or 6.5 percent of precipitation in 1988, and 3,430 x 10^3 gallons or 10.3 percent of precipitation in 1989.

The tile drain at the Enterline farm is located at a depth that is above the water table most of the time. Therefore, most of the ground-water flow bypasses the tile drain as underflow directly into the adjacent stream or into ground water. It only flows during and after precipitation events as contrasted from the Halifax farm where the tile drain is below the water table. The Enterline tile system also has several gravel inlets which allow surface water to enter the tile drain, whereas the Halifax system does not.

The average measured nitrite plus nitrate concentrations from the tile drain was 5.9 mg/l in 1987, 11.3 mg/l in 1988, and 12.5 mg/l in 1989. The average concentration measured in surface runoff in 1989 was 5.47 mg/l. The water-weighted average concentration of nitrite plus nitrate in the tile drain was 9.03 mg/l in 1987, 8.19 mg/l in 1988, and 9.45 mg/l in 1989. The water-weighted concentration was slightly lower in 1988. Water discharge and fertilizer application was also lower in 1988. However, the water-weighted concentration was highest in 1989 when water discharge was highest and fertilizer was not applied. These concentration are quite similar to the average concentration of well H2 of 10.4 mg/l reported by Taylor and Edwards. Well H2 has the shallowest water-bearing zone and water produced from this well approximates the quality of the shallow ground water in the basin. The quality of the Enterline water discharge reflect a mixture of surface water entering a gravel inlet connected to a tile drain, water infiltrating through the soil and, shallow ground water as the water tables rises to levels affecting the drain.

A comparison of water-weighted concentrations of total nitrogen and total phosphorus, based on the total drainage area (24.63 acres) and on the area planted in corn (12.57 acres) was made. It was assumed that the total nitrogen and total phosphorus contribution from the wooded area was negligible; therefore, the total nitrogen and total phosphorus loads measured came from the corn fields only. Water discharge was prorated on a per acre basis in order to compute the water-weighted concentrations. The yields and mean concentrations nearly doubled when computed on the corn acreage only and probably better represents the response to the agronomic practices. The concentrations based on the total drainage area show the dilution affect of the non-farm area. The adjusted concentrations were comparable to the mean concentrations for the Halifax farm, but are slightly lower.

The 4 to 10 lbs/ac N loss, based on 24.63 acres at Enterline, is similar to the average N loses estimated for farmed Susquehanna River subbasins that are at least 50 perent forested. The intensely farmed Conestoga River basin averages 33 lbs/ac N loss and a 2.44 lbs/ac P loss. The Halifax farm, which does not have non-farm dilution runoff, appears in the high N range, but neither farm remotely approaches the P loss found in the Conestoga or other highly farmed basins.

Total loads of nitrite plus nitrate were 154 pounds in the last six months of 1987, 97.7 pounds in 1988, and 244 pounds in 1989. Surface runoff accounted for 19.4 pounds in 1989. Total phosphorus loads were 1.39 pounds in 1987, 2.63 pounds in 1988, and 1.40 pounds in 1989. Surface runoff accounted for 0.46 pounds in 1989. Nutrient loadings from the Enterline farm varied directly with water discharge.

Results of pesticide analyses generally reflected the pesticides applied on the Enterline farm.

Accounting for nitrogen and phosphorus inputs and outputs showed large differences between inputs and outputs. This was due to the nature of the tile drain system, where there was surface water contamination and large quantities of ground water flow not being accounted for. However, data collected from the Enterline farm is valuable because there must be other systems that are similar. The nutrient concentration and loading data at the Enterline farm did not show any decreasing trend even though the farmer did not apply any fertilizer in 1989. However, soil analysis data show that residual soil N decreased from 55 lbs/ac in the spring to 17 lbs/ac in the fall, while the residual soil P decreased from 1.1 lbs/ac in the spring to 0.2 lb/ac in the fall.

REFERENCE

Ott, A. N., Reed, L. A., Takita, C. S., Edwards, R. E., and Bollinger, S. W., 1991, Loads and yields of nutrients and suspended sediment transported in the Susquehanna River Basin, 1985-1989: Susquehanna River Basin Commission, 256 p. (In review).

Taylor, L. E. and Edwards, R. E., 1989, Quality of groundwater at two farms in central Pennsylvania: Susquehanna River Basin Commission, 18 p.

U.S. Department of Agriculture, 1972, Soil survey, Dauphin County, Pennsylvania; 104 p.

APPENDIX A

NUTRIENT SUMMARY STATISTICS

```
            -- Nutrient Summary Statistics --

                 Station: Halifax Tile Drain
        Date start:  870701       Date end:  871231
               Total number of samples =  68


-----------------------------------------------------------------
               Flow      NH3      TKN      NO23       TP      TOC
             --------  -----------------------------------------
              gal/hr                       mg/l
-----------------------------------------------------------------

Maximum      8,402.40  7.81     40.80     33.20      4.95  114.00
Minimum          0.50  0.02*     0.20*    16.10      0.01*   1.00*

Average      1,538.89  0.22      1.31     26.21      0.16    3.30
Median         270.36  0.08      0.43     26.50      0.08    1.20

#Analyses          68  68        58        68        68      68
# < Limit           0  20         9         0         4      21
# Missing           0   0        10         0         0       0

-----------------------------------------------------------------

* Indicates critical limit
```

-- Nutrient Summary Statistics --

Station: Halifax Tile Drain
Date start: 870701 Date end: 870930
Total number of samples = 56

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	8,402.40	7.81	40.80	31.50	4.95	114.00
Minimum	0.50	0.02*	0.20*	16.10	0.01*	1.00*
Average	1,754.70	0.27	1.57	26.42	0.19	3.83
Median	340.74	0.09	0.50	26.50	0.10	1.30
#Analyses	56	56	46	56	56	56
# < Limit	0	9	3	0	3	15
# Missing	0	0	10	0	0	0

* Indicates critical limit

Date start: 871001 Date end: 871231
Total number of samples = 12

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	3,891.60	0.04	1.72	33.20	0.03	1.50
Minimum	0.50	0.02*	0.20*	20.90	0.02*	1.00*
Average	531.79	0.01	0.32	25.23	0.02	0.83
Median	117.72	0.02*	0.20*	25.20	0.03	1.00*
#Analyses	12	12	12	12	12	12
# < Limit	0	11	6	0	1	6
# Missing	0	0	0	0	0	0

* Indicates critical limit

-- Nutrient Summary Statistics --

Station: Halifax Tile Drain
Date start: 880101 Date end: 881231
Total number of samples = 50

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	1,271.50	0.22	0.78	22.80	4.07	7.20
Minimum	0.50	0.02*	0.20*	13.40	0.02*	1.00*
Average	262.64	0.02	0.17	19.21	0.20	1.48
Median	81.72	0.02*	0.20*	19.40	0.03	1.05
#Analyses	49	50	50	50	50	48
# < Limit	0	25	37	0	4	16
# Missing	1	0	0	0	0	2

* Indicates critical limit

-- Nutrient Summary Statistics --

Station: Halifax Tile Drain
Date start: 880101 Date end: 880331
Total number of samples = 12

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	339.48	0.04	0.64	22.30	4.07	7.20
Minimum	0.50	0.02*	0.20*	17.20	0.02*	1.00*
Average	117.65	0.01	0.21	20.47	0.46	1.59
Median	81.72	0.02*	0.20*	20.65	0.02	1.05
#Analyses	12	12	12	12	12	12
# < Limit	0	7	7	0	2	5
# Missing	0	0	0	0	0	0

* Indicates critical limit

Date start: 880401 Date end: 880630
Total number of samples = 26

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	1,271.50	0.08	0.24	22.00	3.36	6.80
Minimum	7.56	0.02*	0.20*	13.40	0.02*	1.00*
Average	355.71	0.02	0.11	18.78	0.16	1.34
Median	109.44	0.02*	0.20*	19.10	0.04	1.10
#Analyses	26	26	26	26	26	24
# < Limit	0	13	23	0	1	7
# Missing	0	0	0	0	0	2

* Indicates critical limit

```
              -- Nutrient Summary Statistics --

                  Station: Halifax Tile Drain
          Date start:  880701      Date end:  880930
                 Total number of samples =  5


 ------------------------------------------------------------
                 Flow     NH3     TKN     NO23      TP    TOC
               -------- ---------------------------------------
                gal/hr                    mg/l
 ------------------------------------------------------------

 Maximum        11.88    0.22    0.31   18.70     0.05   1.80
 Minimum         2.16    0.02*   0.20*  17.40     0.02   1.00*

 Average         7.12    0.06    0.14   17.84     0.03   1.06
 Median          7.56    0.03    0.20*  17.60     0.03   1.00*

  #Analyses        5       5       5       5        5      5
  # < Limit        0       1       4       0        0      1
  # Missing        0       0       0       0        0      0

------------------------------------------------------------

* Indicates critical limit
```

```
          Date start:  881001      Date end:  881231
                 Total number of samples =  7


 ------------------------------------------------------------
                 Flow     NH3     TKN     NO23      TP    TOC
               -------- ---------------------------------------
                gal/hr                    mg/l
 ------------------------------------------------------------

 Maximum     1,040.70    0.02    0.78   22.80     0.12   5.90
 Minimum        17.28    0.02*   0.20*  15.00     0.02*  1.00*

 Average       362.27    0.01    0.34   19.62     0.04   2.08
 Median         98.28    0.02*   0.31   21.42     0.03   1.10

  #Analyses        6       7       7       7        7      7
  # < Limit        0       4       3       0        1      3
  # Missing        1       0       0       0        0      0

 ------------------------------------------------------------

 * Indicates critical limit
```

-- Nutrient Summary Statistics --

Station: Halifax Tile Drain
Date start: 890101 Date end: 891231
Total number of samples = 71

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	7,912.00	0.07	0.64	26.30	0.19	5.00
Minimum	0.00	0.02*	0.20*	16.00	0.02*	1.00*
Average	811.80	0.01	0.19	21.60	0.04	1.44
Median	137.16	0.02*	0.20*	21.50	0.03	1.30
#Analyses	70	71	71	71	71	70
# < Limit	0	49	42	0	1	12
# Missing	1	0	0	0	0	1

* Indicates critical limit

```
            -- Nutrient Summary Statistics --

                Station: Halifax Tile Drain
        Date start:  890101     Date end:  890331
              Total number of samples =  21


------------------------------------------------------------
                 Flow     NH3     TKN     NO23      TP    TOC
               -------  ----------------------------------------
               gal/hr                     mg/l
------------------------------------------------------------

Maximum        716.40   0.04    0.29   25.00    0.13   3.10
Minimum          4.32   0.02*   0.20*  19.10    0.02*  1.00*

Average        152.74   0.01    0.12   21.76    0.03   1.39
Median         116.64   0.02*   0.20*  21.50    0.03   1.20

 #Analyses        20     21      21      21      21     21
 # < Limit         0     14      17       0       1      5
 # Missing         1      0       0       0       0      0

------------------------------------------------------------

* Indicates critical limit



        Date start:  890401     Date end:  890630
              Total number of samples =  20


------------------------------------------------------------
                 Flow     NH3     TKN     NO23      TP    TOC
               -------  ----------------------------------------
               gal/hr                     mg/l
------------------------------------------------------------

Maximum      6,739.20   0.02    0.59   26.30    0.06   1.80
Minimum          0.05   0.02*   0.20*  16.20    0.02   1.00*

Average      1,123.04   0.01    0.19   22.23    0.03   1.30
Median         261.72   0.02*   0.20*  22.30    0.04   1.30

 #Analyses        20     20      20      20      20     19
 # < Limit         0     13      12       0       0      2
 # Missing         0      0       0       0       0      1

------------------------------------------------------------

* Indicates critical limit
```

-- Nutrient Summary Statistics --

Station: Halifax Tile Drain
Date start: 890701 Date end: 890930
Total number of samples = 15

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	7,912.00	0.07	0.64	25.40	0.19	5.00
Minimum	24.12	0.02*	0.20*	16.00	0.02	1.00*
Average	932.13	0.02	0.24	21.29	0.05	1.96
Median	81.72	0.02*	0.21	21.50	0.03	1.50
#Analyses	15	15	15	15	15	15
# < Limit	0	8	7	0	0	1
# Missing	0	0	0	0	0	0

* Indicates critical limit

Date start: 891001 Date end: 891231
Total number of samples = 15

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	6,519.60	0.02	0.50	23.00	0.09	3.10
Minimum	11.88	0.02*	0.20*	18.90	0.02	1.00*
Average	1,155.23	0.01	0.25	20.84	0.03	1.19
Median	137.16	0.02*	0.25	21.00	0.03	1.20
#Analyses	15	15	15	15	15	15
# < Limit	0	14	6	0	0	4
# Missing	0	0	0	0	0	0

* Indicates critical limit

-- Nutrient Summary Statistics --

Station: Halifax Spring
Date start: 870701 Date end: 871231
Total number of samples = 24

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	339.22	0.05	1.51	29.80	0.09	5.60
Minimum	2.54	0.02*	0.20*	17.20	0.02*	1.00*
Average	133.68	0.01	0.22	22.43	0.03	1.09
Median	119.27	0.02*	0.20*	21.84	0.02*	1.00*
#Analyses	18	24	24	24	24	24
# < Limit	0	18	16	0	3	19
# Missing	6	0	0	0	0	0

* Indicates critical limit

-- Nutrient Summary Statistics --

Station: Halifax Spring
Date start: 870701 Date end: 870930
Total number of samples = 10

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	16.44	0.04	0.30	28.60	0.06	4.30
Minimum	2.54	0.02*	0.20*	18.00	0.02	1.00*
Average	9.21	0.01	0.17	22.53	0.03	1.38
Median	8.93	0.02*	0.20*	22.20	0.04	1.00*
#Analyses	4	10	10	10	10	10
# < Limit	0	7	5	0	0	6
# Missing	6	0	0	0	0	0

* Indicates critical limit

Date start: 871001 Date end: 871231
Total number of samples = 14

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	339.22	0.04	1.51	29.80	0.03	5.60
Minimum	53.80	0.02*	0.20*	19.70	0.02*	1.00*
Average	169.25	0.01	0.28	23.28	0.02	0.91
Median	158.46	0.02*	0.20*	22.35	0.02*	1.00*
#Analyses	14	14	14	14	14	14
# < Limit	0	10	9	0	3	12
# Missing	0	0	0	0	0	0

* Indicates critical limit

```
            -- Nutrient Summary Statistics --

                 Station: Halifax Spring
        Date start:  880101       Date end:  881231
             Total number of samples =  57


--------------------------------------------------------------
              Flow     NH3      TKN      NO23       TP     TOC
            -------- ----------------------------------------
             gal/hr                      mg/l
--------------------------------------------------------------

Maximum      494.76   0.12     0.90     22.30      0.51    5.50
Minimum        3.17   0.02*    0.20*     7.09      0.02*   1.00*

Average      149.01   0.01     0.13     19.02      0.04    0.77
Median        52.48   0.02*    0.20*    19.40      0.03    1.00*

 #Analyses      53     56       57        57        57      57
 # < Limit       0     38       51         0         8      47
 # Missing       4      1        0         0         0       0

--------------------------------------------------------------

* Indicates critical limit
```

-- Nutrient Summary Statistics --

Station: Halifax Spring
Date start: 880101 Date end: 880331
Total number of samples = 11

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	494.76	0.04	0.56	22.30	0.08	2.40
Minimum	40.76	0.02*	0.20*	16.80	0.02*	1.00*
Average	191.71	0.01	0.15	20.46	0.03	0.67
Median	103.86	0.02*	0.20*	20.50	0.02*	1.00*
#Analyses	10	11	11	11	11	11
# < Limit	0	9	9	0	3	10
# Missing	1	0	0	0	0	0

* Indicates critical limit

Date start: 880401 Date end: 880630
Total number of samples = 24

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	463.00	0.06	0.28	21.30	0.12	2.20
Minimum	19.02	0.02*	0.20*	15.00	0.02*	1.00*
Average	205.77	0.01	0.10	19.34	0.03	0.79
Median	79.04	0.02*	0.20*	19.59	0.03	1.00*
#Analyses	23	24	24	24	24	24
# < Limit	0	15	23	0	2	18
# Missing	1	0	0	0	0	0

* Indicates critical limit

-- Nutrient Summary Statistics --

Station: Halifax Spring
Date start: 880701 Date end: 880930
Total number of samples = 12

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	41.98	0.12	0.90	19.36	0.51	5.50
Minimum	11.12	0.02*	0.20*	7.09	0.02*	1.00*
Average	22.48	0.02	0.16	17.07	0.07	0.95
Median	21.14	0.02*	0.20*	18.50	0.03	1.00*
#Analyses	10	11	12	12	12	12
# < Limit	0	6	11	0	1	10
# Missing	2	1	0	0	0	0

* Indicates critical limit

Date start: 881001 Date end: 881231
Total number of samples = 10

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	407.58	0.02	0.25	22.10	0.13	1.80
Minimum	3.17	0.02*	0.20*	14.30	0.02*	1.00*
Average	102.30	0.01	0.12	19.05	0.03	0.63
Median	40.73	0.02*	0.20*	18.82	0.03	1.00*
#Analyses	10	10	10	10	10	10
# < Limit	0	8	8	0	2	9
# Missing	0	0	0	0	0	0

* Indicates critical limit

```
                    -- Nutrient Summary Statistics --

                        Station: Halifax Spring
              Date start:  890101      Date end:  891231
                   Total number of samples =  67

 ------------------------------------------------------------------
                  Flow      NH3      TKN      NO23       TP     TOC
                --------  ----------------------------------------
                 gal/hr                       mg/l
 ------------------------------------------------------------------

 Maximum         807.48    0.08     0.52    29.10      0.36    2.80
 Minimum          30.41    0.02*    0.20*   10.63      0.02*   0.00*

 Average         233.13    0.01     0.17    22.08      0.04    0.82
 Median          143.37    0.02*    0.20*   22.30      0.03    0.50
                            *        *

  #Analyses         67     67       67       67        67      67
  # < Limit          0     56       43        0         3      42
  # Missing          0      0        0        0         0       0

 ------------------------------------------------------------------

* Indicates critical limit
```

```
            -- Nutrient Summary Statistics --

                  Station: Halifax Spring
        Date start:  890101      Date end:  890331
             Total number of samples =  15


-------------------------------------------------------------
             Flow      NH3      TKN      NO23      TP     TOC
            -------  ------------------------------------------
             gal/hr                       mg/
---------------------------------------------------------------

Maximum       427.96   0.04     0.10    24.50     0.06    1.40
Minimum        30.41   0.02*    0.20*   17.10     0.02*   1.00*

Average       181.43   0.01     0.10    21.38     0.02    0.60
Median        143.37   0.02*    0.20*   21.50     0.03    1.00*

 #Analyses      15      15       15       15       15      15
 # < Limit       0      13       15        0        2      13
 # Missing       0       0        0        0        0       0

----------------------------------------------------------------

* Indicates critical limit



        Date start:  890401      Date end:  890630
             Total number of samples =  19


----------------------------------------------------------------
              Flow      NH3      TKN      NO23      TP     TOC
             -------  ------------------------------------------
             gal/hr                       mg/l
----------------------------------------------------------------

Maximum       778.12   0.02     0.52    29.10     0.36    2.40
Minimum        48.63   0.02*    0.20*   19.60     0.02    0.00*

Average       323.36   0.01     0.19    22.83     0.06    0.88
Median        383.82   0.02*    0.20*   23.00     0.03    0.50

 #Analyses      19      19       19       19       19      19
 # < Limit       0      14       10        0        0       9
 # Missing       0       0        0        0        0       0

----------------------------------------------------------------

* Indicates critical limit
```

```
                  -- Nutrient Summary Statistics --

                        Station: Halifax Spring
             Date start:  890701       Date end:  890930
                    Total number of samples =   15


 ---------------------------------------------------------------------
                   Flow      NH3       TKN      NO23       TP      TOC
                 --------  ---------------------------------------------
                  gal/hr                        mg/l
 ---------------------------------------------------------------------

  Maximum        807.48    0.08      0.35     25.00      0.12     2.80
  Minimum         59.04    0.02*     0.20*    21.30      0.02*    1.00*

  Average        240.45    0.01      0.17     23.22      0.03     1.00
  Median         116.94    0.02*     0.20*    23.50      0.03     1.00*

   #Analyses        15       15        15        15        15       15
   # < Limit         0       11         9         0         1        7
   # Missing         0        0         0         0         0        0

 ---------------------------------------------------------------------

* Indicates critical limit



             Date start:  891001       Date end:  891231
                    Total number of samples =   18


 ---------------------------------------------------------------------
                   Flow      NH3       TKN      NO23       TP      TOC
                 --------  ---------------------------------------------
                  gal/hr                        mg/l
 ---------------------------------------------------------------------

  Maximum        518.79    0.01      0.44     24.90      0.06     2.30
  Minimum         36.06    0.02*     0.20*    10.63      0.02     1.00*

  Average        174.86    0.01      0.21     20.93      0.03     0.77
  Median         118.11    0.02*     0.20*    21.80      0.03     1.00*

   #Analyses        18       18        18        18        18       18
   # < Limit         0       18         9         0         0       13
   # Missing         0        0         0         0         0        0

 ---------------------------------------------------------------------

* Indicates critical limit
```

```
            -- Nutrient Summary Statistics --

                  Station: Halifax Surface
        Date start:  890101       Date end:  891231
             Total number of samples =  45


-------------------------------------------------------------
                Flow      NH3      TKN      NO23       TP      TOC
              --------  ----------------------------------------
               gal/hr                       mg/l
-------------------------------------------------------------

Maximum   1,5596.00   0.49     5.05    23.70      2.04    38.60
Minimum        0.50   0.02*    1.00*    0.15      0.10     1.00*

Average    3,231.72   0.12     1.83     5.84      0.88    15.19
Median     2,193.70   0.10     1.31     3.96      0.76    14.10

 #Analyses       41     45       45       45        45       45
 # < Limit        0      1        1        0         0        1
 # Missing        4      0        0        0         0        0

-------------------------------------------------------------

* Indicates critical limit



        Date start:  890401       Date end:  890630
              Total number of samples =  2


-------------------------------------------------------------
                Flow      NH3      TKN      NO23       TP      TOC
              --------  ----------------------------------------
               gal/hr                       mg/l
-------------------------------------------------------------

Maximum    1,704.20   0.04     1.31    19.10      0.33     6.90
Minimum       30.00   0.02     0.83    17.20      0.17     6.50

Average      867.10   0.03     1.06    18.15      0.25     6.70
Median       867.10   0.03     1.07    18.15      0.25     6.70

 #Analyses        2      2        2        2         2        2
 # < Limit        0      0        0        0         0        0
 # Missing        0      0        0        0         0        0

-------------------------------------------------------------

* Indicates critical limit
```

-- Nutrient Summary Statistics --

Station: Halifax Surface
Date start: 890701 Date end: 890930
Total number of samples = 26

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	15,596.00	0.25	5.05	23.70	2.04	38.60
Minimum	898.90	0.02	0.93	0.31	0.13	5.50
Average	4,191.16	0.10	2.15	5.15	1.04	20.10
Median	2,389.30	0.08	1.69	3.92	0.83	17.45
#Analyses	25	26	26	26	26	26
# < Limit	0	0	0	0	0	0
# Missing	1	0	0	0	0	0

* Indicates critical limit

Date start: 891001 Date end: 891231
Total number of samples = 17

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	3,816.00	0.49	4.40	20.10	1.38	34.80
Minimum	0.50	0.02*	1.00*	0.15	0.10	1.00*
Average	1,856.22	0.16	1.43	5.46	0.71	8.67
Median	2,193.60	0.12	1.01	0.46	0.76	4.90
#Analyses	14	17	17	17	17	17
# < Limit	0	1	1	0	0	1
# Missing	3	0	0	0	0	0

* Indicates critical limit

-- Nutrient Summary Statistics --

Station: Enterline Tile Drain
Date start: 870701 Date end: 871231
Total number of samples = 105

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	9,133.20	0.61	2.00	26.52	1.65	12.20
Minimum	0.50	0.02*	0.12*	0.50	0.01*	1.00*
Average	900.94	0.11	0.66	5.89	0.25	4.39
Median	563.40	0.08	0.68	6.82	0.07	2.60
#Analyses	105	105	95	105	105	105
# < Limit	0	7	17	0	3	33
# Missing	0	0	10	0	0	0

* Indicates critical limit

-- Nutrient Summary Statistics --

Station: Enterline Tile Drain
Date start: 870701 Date end: 870930
Total number of samples = 94

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	9,133.20	0.61	2.00	26.52	1.65	12.20
Minimum	0.50	0.02*	0.12*	0.50	0.01*	1.00*
Average	915.93	0.12	0.72	5.52	0.27	4.80
Median	563.40	0.10	0.80	6.38	0.17	3.90
#Analyses	94	94	84	94	94	94
# < Limit	0	1	9	0	2	25
# Missing	0	0	10	0	0	0

* Indicates critical limit

Date start: 871001 Date end: 871231
Total number of samples = 11

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	3,186.70	0.04	1.34	13.40	0.41	2.60
Minimum	88.20	0.02*	0.20*	5.06	0.02*	1.00*
Average	772.84	0.01	0.25	8.99	0.06	0.92
Median	285.48	0.02*	0.20*	9.24	0.02*	1.00*
#Analyses	11	11	11	11	11	11
# < Limit	0	6	8	0	1	8
# Missing	0	0	0	0	0	0

* Indicates critical limit

```
              -- Nutrient Summary Statistics --

                 Station: Enterline Tile Drain
        Date start:  880101      Date end:  881231
                 Total number of samples =  36


------------------------------------------------------------
                 Flow      NH3     TKN     NO23     TP    TOC
              --------  ------------------------------------
                gal/hr                  mg/l
------------------------------------------------------------

Maximum     3,379.60   4.29    4.04    53.00    1.76   6.60
Minimum         0.36   0.02*   0.20*    6.16    0.02*  1.00*

Average     1,020.97   0.28    0.41    11.33    0.21   1.51
Median        632.88   0.04    0.20*    8.47    0.04   1.10

 #Analyses        35     36      36       36      36     34
 # < Limit         0      9      18        0       4     14
 # Missing         1      0       0        0       0      2

------------------------------------------------------------

* Indicates critical limit



        Date start:  880101      Date end:  880331
                 Total number of samples =  12


------------------------------------------------------------
                 Flow      NH3     TKN     NO23     TP    TOC
              --------  ------------------------------------
                gal/hr                  mg/l
------------------------------------------------------------

Maximum     2,321.20   0.14    1.22    12.30    1.76   6.60
Minimum        15.48   0.02*   0.20*    6.16    0.02*  1.00*

Average       572.86   0.04    0.26     7.85    0.47   1.48
Median        531.00   0.02*   0.20*    7.14    0.02*  1.00*

 #Analyses        12     12      12       12      12     12
 # < Limit         0      7       5        0       3      7
 # Missing         0      0       0        0       0      0

------------------------------------------------------------

 * Indicates critical limit
```

-- Nutrient Summary Statistics --

Station: Enterline Tile Drain
Date start: 880401 Date end: 880630
Total number of samples = 22

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	3,379.60	4.29	4.04	53.00	0.58	4.90
Minimum	0.36	0.02*	0.20*	7.26	0.02*	1.00*
Average	1,311.10	0.43	0.51	12.11	0.08	1.55
Median	1,008.32	0.07	0.20*	8.70	0.05	1.20
#Analyses	22	22	22	22	22	20
# < Limit	0	2	11	0	1	7
# Missing	0	0	0	0	0	2

* Indicates critical limit

Date start: 881001 Date end: 881231
Total number of samples = 2

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	15.48	0.05	0.10	28.00	0.04	1.60
Minimum	15.48	0.03	0.20	19.14	0.04	1.10
Average	15.48	0.04	0.10	23.57	0.04	1.35
Median	15.48	0.04	0.20	23.57	0.04	1.35
#Analyses	1	2	2	2	2	2
# < Limit	0	0	2	0	0	0
# Missing	1	0	0	0	0	0

* Indicates critical limit

-- Nutrient Summary Statistics --

Station: Enterline Tile Drain
Date start: 890101 Date end: 891231
Total number of samples = 50

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	3,787.20	0.08	2.00	25.40	0.19	5.90
Minimum	0.36	0.02*	0.06*	0.90	0.02*	1.00*
Average	977.99	0.01	0.23	12.46	0.03	1.36
Median	334.26	0.02*	0.10	10.20	0.03	1.00*
#Analyses	46	50	50	50	50	50
# < Limit	0	32	26	0	7	25
# Missing	4	0	0	0	0	0

* Indicates critical limit

-- Nutrient Summary Statistics --

Station: Enterline Tile Drain
Date start: 890101 Date end: 890331
Total number of samples = 19

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	632.00	0.08	0.55	25.40	0.05	2.80
Minimum	0.36	0.02*	0.20*	11.09	0.02*	1.00*
Average	217.75	0.02	0.15	19.42	0.02	1.00
Median	169.92	0.02*	0.20*	20.30	0.03	1.00*
#Analyses	18	19	19	19	19	19
# < Limit	0	10	14	0	5	10
# Missing	1	0	0	0	0	0

* Indicates critical limit

Date start: 890401 Date end: 890630
Total number of samples = 16

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	3,787.20	0.05	0.54	14.00	0.04	4.00
Minimum	111.96	0.02*	0.06*	5.81	0.02*	1.00*
Average	1,741.07	0.01	0.20	8.94	0.03	1.50
Median	1,374.10	0.02*	0.23	8.68	0.03	1.25
#Analyses	14	16	16	16	16	16
# < Limit	0	13	6	0	2	7
# Missing	2	0	0	0	0	0

* Indicates critical limit

```
           -- Nutrient Summary Statistics --

              Station: Enterline Tile Drain
       Date start:  890701      Date end:  890930
              Total number of samples =  4


------------------------------------------------------------
                  Flow      NH3      TKN      NO23      TP      TOC
                --------  ----------------------------------------
                 gal/hr                     mg/l
------------------------------------------------------------

Maximum       2,019.90    0.04     0.31     7.02     0.07     5.90
Minimum           9.00    0.02*    0.20*    5.81     0.04     1.00*

Average       1,173.43    0.02     0.24     6.33     0.05     2.82
Median        1,491.40    0.02     0.28     6.26     0.06     2.45

 #Analyses           3       4        4        4        4        4
 # < Limit           0       1        1        0        0        1
 # Missing           1       0        0        0        0        0

------------------------------------------------------------

* Indicates critical limit



       Date start:  891001      Date end:  891231
             Total number of samples =  11


------------------------------------------------------------
                  Flow      NH3      TKN      NO23      TP      TOC
                --------  ----------------------------------------
                 gal/hr                     mg/l
------------------------------------------------------------

Maximum       3,787.20    0.05     2.00    11.40     0.19     3.40
Minimum          24.48    0.02*    0.20*    0.90     0.02     1.00*

Average       1,197.54    0.01     0.39     7.81     0.05     1.27
Median          632.88    0.02*    0.23     9.44     0.03     1.00*

 #Analyses          11      11       11       11       11       11
 # < Limit           0       8        5        0        0        7
 # Missing           0       0        0        0        0        0

------------------------------------------------------------

* Indicates critical limit
```

-- Nutrient Summary Statistics --

Station: Enterline Surface
Date start: 890101 Date end: 891231
Total number of samples = 35

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	4,683.60	0.38	1.30	14.30	0.60	35.00
Minimum	0.36	0.02*	0.20*	0.04*	0.02*	1.00*
Average	804.73	0.02	0.51	5.47	0.09	9.01
Median	187.20	0.02*	0.49	5.15	0.06	4.10
#Analyses	32	35	35	35	35	35
# < Limit	0	21	3	13	1	1
# Missing	3	0	0	0	0	0

* Indicates critical limit

Date start: 890401 Date end: 890630
Total number of samples = 14

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	4,109.70	0.38	1.30	13.80	0.60	5.30
Minimum	10.40	0.02*	0.20*	0.29	0.02*	1.00*
Average	1,268.16	0.05	0.40	9.72	0.07	3.03
Median	802.40	0.03	0.37	10.85	0.04	3.20
#Analyses	11	14	14	14	14	14
# < Limit	0	5	3	0	1	1
# Missing	3	0	0	0	0	0

* Indicates critical limit

-- Nutrient Summary Statistics --

Station: Enterline Surface
Date start: 890701 Date end: 890930
Total number of samples = 3

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	270.40	0.05	0.60	5.32	0.07	10.60
Minimum	87.10	0.02	0.27	3.96	0.05	4.40
Average	190.10	0.03	0.41	4.86	0.06	6.96
Median	212.80	0.02	0.38	5.32	0.06	5.90
#Analyses	3	3	3	3	3	3
# < Limit	0	0	0	0	0	0
# Missing	0	0	0	0	0	0

* Indicates critical limit

Date start: 891001 Date end: 891231
Total number of samples = 18

	Flow	NH3	TKN	NO23	TP	TOC
	gal/hr	mg/l				
Maximum	4,683.60	0.02	1.06	14.30	0.35	35.00
Minimum	0.36	0.02*	0.38	0.04*	0.02	1.00
Average	623.96	0.01	0.61	2.26	0.12	14.00
Median	81.18	0.02*	0.60	0.04*	0.11	15.00
#Analyses	18	18	18	18	18	18
# < Limit	0	16	0	13	0	0
# Missing	0	0	0	0	0	0

* Indicates critical limit

SUSQUEHANNA RIVER BASIN COMMISSION
DEC. 24, 1970
N.Y.
PA.
MD.
UNITED STATES • PENNSYLVANIA • NEW YORK • MARYLAND